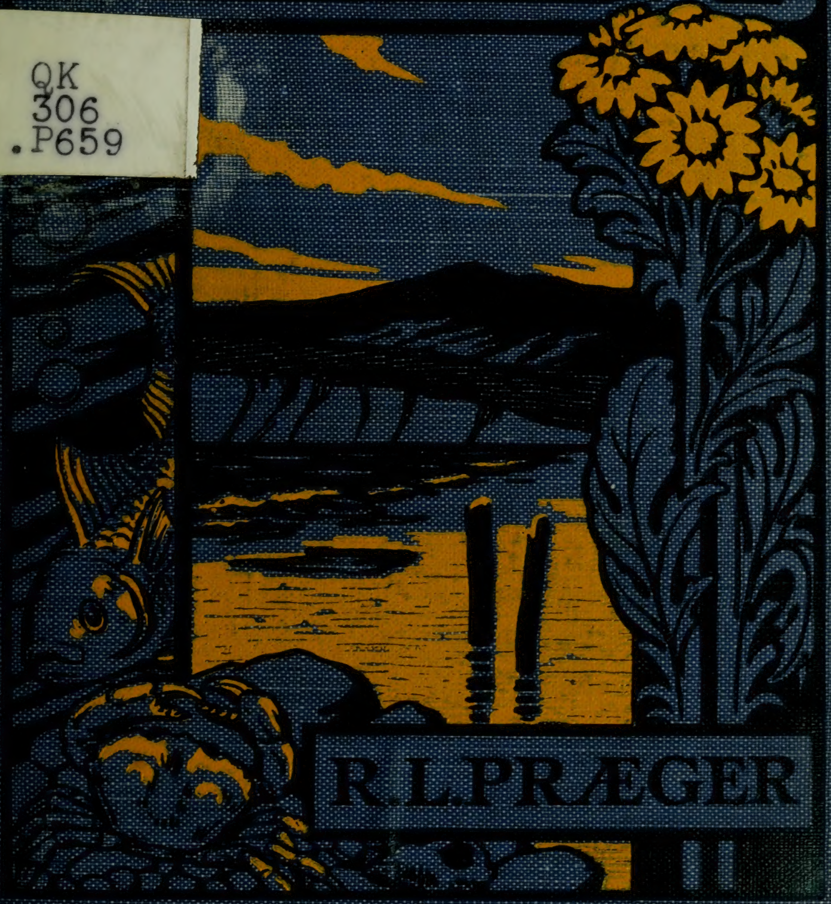
THE NATURE LOVER'S SERIES

ASPECTS OF PLANT LIFE



R. L. PRÆGER

Desert Types.

(For names of species, see page 7.)

NATURE LOVER'S SERIES

ASPECTS OF
PLANT LIFE

WITH SPECIAL REFERENCE TO THE BRITISH FLORA

BY

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"OPEN-AIR STUDIES IN BOTANY," "IRISH TOPOGRAPHICAL BOTANY,"
"A TOURIST'S FLORA OF THE WEST OF IRELAND,"
"WEEDS," ETC.

WITH COLOURED FRONTISPIECE AND NUMEROUS
BLACK AND WHITE ILLUSTRATIONS

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PREFACE

In the following chapters an attempt is made to deal, in a quite elementary way, with some of the wider aspects of plant life—to discuss questions which arise in the mind from a contemplation of the vegetation which clothes with a green mantle the surface of our own country. No essay is made to enumerate or define the plants to be met with in the different types of ground, or in the different geographical areas, which go to make up the British Isles: there are already plenty of excellent handbooks and local floras in which that aspect of native plant life is treated. The vegetation is taken rather as a whole, and its whence, and when, and how are considered with as little of technical phraseology as the subject allows. The influence on plants of their physical environment, and the intimate inter-relations of the vegetable kingdom with the other great manifestation of organic life, the animal kingdom, are briefly considered, as is also the unique relation existing between the plant world and the human race.

These chapters are intended to be used in conjunction with simple observations in the field, such as any person of enquiring mind, unversed in science, may

be tempted to make during idle hours on a summer holiday.

To Professor G. H. Carpenter and Mr. W. B. Wright I am indebted for suggestions and emendations where I have trespassed on the domains of zoology and geology respectively.

R. Ll. P.

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PLANT LIFE

CHAPTER I

ON FARLETON FELL

"I got up the mountain edge, and from the top saw the world stretcht out, cornlands and forest, the river winding among meadow-flats, and right off, like a hem of the sky, the moving sea."—MAURICE HEWLETT: *Pan and the Young Shepherd.*

TRAVELLING from Scotland by the London and North-Western Railway, as the train roars down the long incline which leads from Shap to the coastal plain of Lancashire, the eye catches, on the left-hand side, a strange grey hill of bare rock rising abruptly, the last outpost of the mountains. It is so different in appearance from the Westmorland fells which have just been traversed, that one looks at it with curiosity, and desires an opportunity of a nearer acquaintance. During the preceding half-hour we have been passing through country of the type that is familiar in the Lake District and in Wales—picturesque ridgy hills with rocky or grassy slopes, and fields and trees occupying the lower grounds. But over much of the surface of this grey hill there appear to be scarcely any plants. A dense scrub of Hazel and other small trees clings to its screes in patches, but the continuous mantle of vegetation is lacking.

The train speeds on through fertile ground with ripening crops and woods standing dense and green, and now on the right, where the low land merges with the sea, we view salt-marshes, which display yet another type of plant growth. Here trees and shrubs are absent, and the low-growing grey and green plants look fleshy and stunted.

In the last thirty miles, indeed, since the train left the summit of Shap, we have seen a number of very different types of vegetation, which appear associated with different types of landscape—the moory uplands, the naked limestone, the deep woods, the desolate salt-marsh. Let us in imagination climb the steep scarp of Farleton Fell, the grey hill of our opening sentence, and consider at leisure some aspects of this teeming plant world and its relations to the Earth on which it grows.

Clambering through a wilderness of stony screes we emerge at length on a bare grey tableland on which, in contrast to the rich country below, vegetation is strangely sparse, and bare rock is everywhere in evidence. If we let the eye sweep round the horizon, we note a similar contrast displayed on broader lines. On the one hand is the mountain-land, with its carpet of grass and heather extending to the very summits; on the other hand the broad expanses of bare sand and mud fringing Morecambe Bay, apparently devoid of any vegetation. And it occurs to us that, before we ponder over the variety and distribution of plant life on this world, we are faced at once with a more profound problem. On this breezy summit, with our minds expanded and stimulated by the sunlight and the breeze, and the

broad and beautiful panorama spread around, we must for a moment try to take a wider outlook than

> Him that vexed his brains, and theories built
> Of gossamer upon the brittle winds,
> Perplexed exceedingly why plants were found
> Upon the mountain-tops, but wondering not
> Why plants were found at all, more wondrous still!

I trust the paraphrase may be pardoned. Why, indeed, should there be plants at all? This great globe, with its whole land surface covered, save at the Poles and in desert regions, with green plants in ten thousand forms, is indeed something to be wondered at. One fascinating question that arises is this: How far is our "lukewarm bullet" unique in its possession of a green plant mantle? Have we any evidence for the supposition that plants exist on the Moon, or on any planets of the solar system other than the Earth?

Vegetation as we know it on our world requires certain physical and chemical conditions for its existence. For instance, a temperature which, at least during the growing season, is well above the freezing-point of water is requisite; yet the temperature must remain a long way below the boiling-point of water; neither could plants as we know them exist in the absence of an atmosphere containing oxygen, carbon dioxide, and water vapour, and incidentally, by its capacity for retaining heat, warding off violent extremes of temperature which otherwise would be a daily and nightly occurrence. What evidence is there as to the condition in these respects of those heavenly bodies which are sufficiently near to allow us to know something of them? To take first our own Moon. Astronomers are agreed that on the Moon

there is neither air nor water; it is a dead mass of solid material, scorched by the Sun by day, held in the grip of appalling frost by night. The Moon was no doubt at some remote period of the Earth's history cast off from that body, and it carried off with it a portion of the Earth's atmosphere, or of the materials which later formed the Earth's atmosphere. But the attraction of the Moon is so small that it was unable to retain these gases on its surface; they diffused into space, much of them returning probably to the Earth, leaving the Moon without any covering of nitrogen or oxygen or hydrogen or water vapour, and thus condemning it to permanent sterility.

As regards Mercury, the planet nearest the Sun, conditions appear equally unfavourable. Mercury has ceased to revolve round the Sun, and continually presents one side towards that luminary. On the opposite side an extraordinarily low temperature prevails, low enough to solidify and bind permanently most of the gases of any possible atmosphere; while, on the other side, the very high temperature, due to perpetual and intense sunshine, has assisted the diffusion into space of the more volatile gases, such as hydrogen, which might have remained unfrozen.

The question of life on Mars, which in many respects suggests conditions resembling those prevailing on our own globe, has long occupied the attention of men of science, among whom strong advocates of a Martian flora and fauna have not been wanting. If we may accept one of the most recent summaries* of the pros and cons of this question, the

* Svante Arrhenius: "The Destinies of the Stars." Translated by J. E. Fries. Putnam, 1918.

conditions are not hopeful. Although an atmosphere exists, it appears to be extremely thin; water vapour seems to be present in only very limited quantity; the temperature is very low, and, except in the warmer portions of the planet during the summer season, would be insufficient to support life. The evidence suggests a frigid climate, with dust-storms whirling over vast deserts and salt seas frozen solid, while near the Poles land and sea alike are buried under snow. Summer produces a slight thawing, but even then the cold, salt-saturated soil would appear to be very unfavourable for plant growth. Arrhenius suggests that the presence of a low vegetation such as snow Algæ near the Poles in summer is as much as could be hoped for under the conditions prevailing on Mars.

Of the planets whose distance from the Sun is small enough to allow heat and light to reach them in quantity sufficient to permit of vegetation such as we know it, there remains Venus, and here at last we meet with conditions suitable for life. Venus possesses an atmosphere densely charged with water vapour, and maintaining a high temperature all the year round. The conditions prevailing there recall, in fact, those believed to have existed on the Earth during the Carboniferous Period, when our great deposits of coal, composed of the remains of tropical plants, were laid down in marshes and steaming lagoons; but on Venus the conditions are still more extreme—the temperature higher, and the moisture much greater, than those of Carboniferous times. If it is allowable to assume that the prevalence of physical and chemical conditions similar to those which in bygone ages supported an abundant vegetation on our globe, would

produce plant life on another world, then we may imagine a luxuriant vegetation on Venus. Whether such an assumption is reasonable is a very interesting and highly speculative question, which the present writer is not competent to discuss. But if one is inclined to indulge in speculation, it may fairly be asked, Why should one limit the possibilities of life to the strict range of conditions under which it is manifested on our Earth? May not the inhabitants of the Sun, ensconced ninety million miles away in a comfortable temperature of 6,500° Centigrade, have long since proved to their own complete satisfaction the impossibility of the existence of life under the appalling conditions of climate prevailing on the Earth? Who can say? There are more things in heaven and earth than are dreamed of in our philosophy. A quotation from one of the foremost of modern men of science helps us to put such flights of thought in their proper perspective. "One can hardly emerge from such thoughts," writes Soddy,* in pointing out the remarkable adaptation of the human eye to the peculiarities of the Sun's light, so as to make the best of that wave-length of which there is most, "without an intuition that, in spite of all, the universal Life Principle, which makes the world a teeming hive, may not be at the sport of every physical condition, may not be entirely confined to a temperature between freezing and boiling points, to an oxygen atmosphere, to the most favourably situated planet of a sun at the right degree of incandescence, as we are almost forced by our experience of life to conclude. Possibly the Great Organizer can operate, under conditions

* F. Soddy: "Matter and Energy," 1912, p. 194.

where we could not for an instant survive, to produce beings we should not, without a special education, recognize as being alive like ourselves."

It is generally conceded that life on our globe began in the water, and thence spread to the land. Very significant in this regard is the fact that all but the highest plants require the presence of external water for the act of fertilization, as the male cell *swims* through water to the ovum. Only the most recently evolved groups have shaken off this ancestral trait; and as regards the whole economy of plants the water relation remains, throughout the entire vegetable kingdom, the most obvious and universally important of the different relations existing between plants and their environment. How vegetable life originated, from what inorganic forms it was evolved, is a secret which science has not yet discovered; but since those dim first beginnings it has never been absent from the Earth, so far as we know, and has increased and multiplied, and passed through a thousand changes to higher and higher forms, till it has attained to the beautiful and bountiful and varied plant world which we know, covering with a green mantle most of the land surface of the globe and filling the shallower lakes and seas; while in its minuter forms it swarms in the soils and waters of the Earth, and its germs pervade the atmosphere.

It is not everywhere even on our hospitable, habitable globe that conditions are suitable for plant growth. The reader will remember that the flat summit of Farleton Fell, where in fancy we still stand, was devoid to a great extent of vegetation; and that the sea-sands and mud-flats out to the westward presented a surface

from which plants appeared to be absent. This question of *deserts*—that is, of areas of the Earth's surface where the prevailing mantle of vegetation is wanting—is an interesting one, and may fittingly detain us for a few minutes. Deserts are produced by the failure of one or more of the conditions which are necessary for plant life. The factors in question may be briefly defined as *temperature*, *light*, *water*, *atmosphere*, and *mineral salts*. The majority of the higher plants have developed a complicated root-system for the purpose of collecting water (containing salts) from the soil, and of anchoring the organism firmly in its chosen abode, so a *soil* is also usually essential. Here on Farleton Fell soil is missing over much of the surface, which is occupied by naked limestone rock. The absence of soil is due to the fact that the material—carbonate of lime—of which the rock is composed is soluble in water, unlike, for instance, the materials of which slate or sandstone rocks are composed; the rains slowly dissolve it, and it passes in solution down through crevices in the strata, leaving behind only a small insoluble residue. This residue, where not also washed away, collects in every little hollow, and lowly plants such as Algæ and Mosses soon discover it and colonize it. Their decayed remains add nutritive material to the little pocket, and help to retain water, and thus prepare the way by degrees for higher forms of life; till at length the crevices become filled with a luxuriant vegetation which, as we shall see later, is of a rather peculiar type. It should be noted that even the bare rock is not so inhospitable as completely to exclude plant life. If we examine it with a lens we shall see

that it is colonized by minute Lichens, many of which have the power of dissolving the limestone, producing tiny burrows in which they live securely.

On the sands and mud-flats a semi-desert exists, due in great measure to the shifting nature of the material and the difficulty which plants find in securing an anchorage in it. But in the upper parts, near high-water mark, a few land plants—notably the Glasswort (*Salicornia europæa*, Fig. 2), a fleshy little

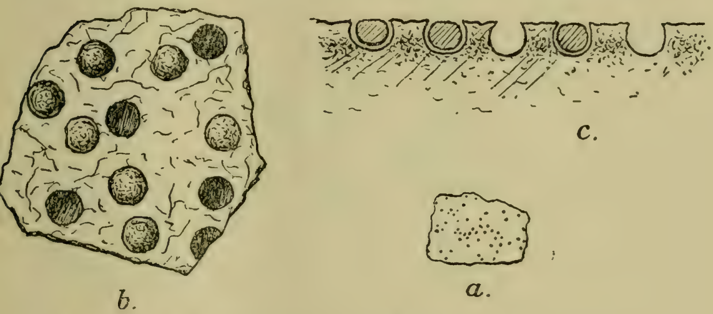


FIG. 1.—A BURROWING LICHEN (VERRUCARIA CALCISEDA), LIVING IN LIMESTONE.

a, Natural size; *b*, greatly enlarged; *c*, section, greatly enlarged.

annual—colonize the dreary flats with tiny forests of dark green branches, and lower down many small Seaweeds flourish. Some of these, ramifying through the surface layers, help to bind together the shifting sand, and by entangling in their branches fresh particles, and by continued growth, tend to raise and consolidate the surface, to render it suitable for the immigration of land plants such as the Glasswort, and thus eventually to reclaim it from the sea.

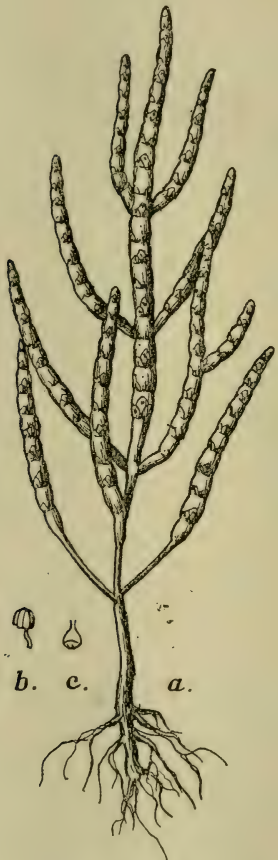


FIG. 2.—GLASSWORT (SALICORNIA EUROPÆA).

a, Plant, $\frac{2}{3}$; *b*, male flower; *c*, female flower, both enlarged.

It is in the depths of the ocean, however, that the greatest deserts of our globe are to be found. The luxuriant Seaweed gardens that decorate the shallower waters of the sea, especially where a rocky bottom provides secure foothold, dwindle rapidly as the depth increases, owing to the diminution of light, and when the coastal fringe is left they cease. In the inky darkness of the ocean depths, amid absolute stillness and a temperature little above freezing, plant life of any sort is unknown. Only the flinty skeletons of diatoms and other minute forms of vegetable life which inhabit the surface layers, raining slowly down throughout the ages, tell that plant life exists in the sea at all.

On land, the larger deserts are found in the coldest and in the hottest regions. Around the North and South Poles lie great areas where the perennial lowness of temperature and the consequent almost continuous covering of snow and ice render plant life impossible. But just as the Eskimo live under conditions which would be wellnigh prohibitive to inhabitants of more temperate regions, so many of the higher as well as the lower plants creep northward far beyond the Arctic Circle, where, awakening from a nine months' winter sleep, they break from the still half-frozen ground to brighten the brief summer with their leaves and flowers and fruit. The flora of Greenland, for instance, which we generally think of as an ice-bound and inhospitable land, numbers some 400 species of Seed Plants. These live mostly on the cliffs and steep ground that fringe the coast, where they are clear of the great icefields which bury the interior of the country, and in many places descend

as broad glaciers into the sea. But the life of these high northern plants is slow and difficult, as is evidenced by their paucity and their stunted stature. Later on we shall have to consider how they adapt themselves to the adverse conditions under which they exist (Chapter VIII.); and we shall find their life problems are reproduced in many respects by those of the interesting alpine plants which may be found nestling in the rock crevices of the higher mountains of our own country.

But the more familiar deserts of the world, those to which the mind turns when we use the term, are mainly due, not to absence of light as in the ocean depths, nor to want of heat as in the polar regions, but to failure of the water-supply. A vast desert region of this kind stretches across Northern Africa from west to east, and onward through Arabia, Southern Persia, and Baluchistan. Another, almost continuous with it, extends from the Caspian Sea across great plains into Central Asia, and on over vast mountain areas into Western China. Other similar deserts, familiar to us in word and picture, are situated in the south-western United States, Mexico, and South Africa. In all these tracts, with their diverse characters and diverse sparse floras, the scarcity of rain is the primary cause of their peculiar features. The dryness prevents a protecting covering of vegetation, and allows heat and cold—both sharply accentuated by the scarcity of the moderating influence of water in either soil or air—to pursue their work of disintegrating the surface, reducing the rocks to sand and dust, which the winds sweep hither and thither. In such circumstances plants exist under

very difficult conditions; yet there are few areas in which the eye will not note some strange vegetable form. In Fig. 3 are illustrated some of the remarkable Mesembryanthemums found in the South African deserts. Here the extremely fleshy leaves, arranged in opposite pairs, produce a sub-globular plant form, a mere mass of watery tissue, which in colour as well as shape appears to mimic the pebbles among which it grows. The frontispiece shows some other types of

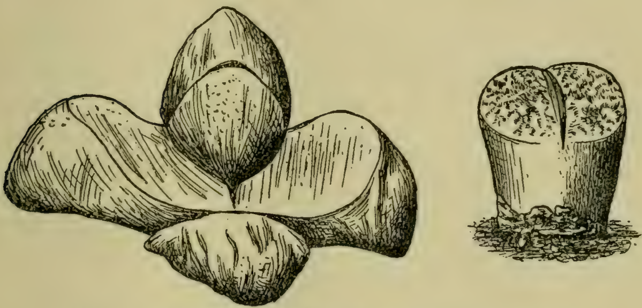


Fig. 3.—Mesembryanthemum Bolusii (left), and M. Lesliei (right), both $\frac{2}{3}$.

desert plants. Another difficulty which desert plants have to contend with is this: continual evaporation from off the land of water charged with mineral salts — in some regions in bygone times, in others still following each brief rainy season—has left the soil highly impregnated with substances, of which common salt is one of the most abundant, which, except in very weak solutions, are deleterious to plant life, since water containing them is absorbed with difficulty by the roots. These old lake-bottoms and

one-time swamps—such as the alkali deserts of Utah—harbour only a limited number of species specially adapted to their arduous conditions of life. The same difficulty, it may be noted, produces the peculiar and specialized flora of the salt-marshes which fringe the broad bay on which we look down from Farleton Fell. Here there is indeed a superabundance of water, but it is so charged with salt that if even the most vigorous species of the fields or woodlands are transplanted into it they will soon be dead; only plants long inured can grow there. Still, the conditions are not so adverse but that a continuous mat of vegetation extends, growing patchy and dying out only where the surface slopes below high-water mark. There we enter a new domain, where another race of plants, so long inured to salt water that they now cannot exist without it, holds possession.

Thus from absolute deserts, such as the floor of the deep sea or the regions surrounding the Poles, we pass to semi-deserts where plants are dotted thinly over the surface, and thence by degrees to closed vegetation of various types, where the plants elbow each other over the whole surface as they do in the grasslands spread around Farleton Fell, in the woods which adjoin them, and on the brown hillsides out to the north. But before we pass to the consideration of the conditions where favourable environment results in a closed vegetation, we may suggest for consideration the following point of view: that for any plant, or group of plants with similar requirements, much of the world is a desert—that is, a place where conditions are such that it cannot live. For each plant there exists, owing to long usage and slow

adaptation to given surroundings, limiting conditions of life: where these conditions are exceeded, the desert supervenes. Thus, the salt-marsh is a desert to almost every plant of the mild open soil of hill or valley, just as the hills and valleys are deserts to most of the inhabitants of the salt-marsh. The alkaline soil of the rock crevices of Farleton Fell is fatal to some of the most abundant plants of the acid peaty soil of the hills, such as Ling (*Calluna vulgaris*) and Bilberry (*Vaccinium Myrtillus*). For another cause—the diminution of light—the deep woods are a desert for many plants of the sunny pastures, and *vice versa*. Plants vary very much as to their degree of adaptability to different soils and different climatic conditions. Some are highly specialized. Our salt-marsh flora, for instance, is, as regards most of its species, confined to its peculiar habitat. If on a map of Europe we coloured in its distribution we should find it formed a ribbon round the coast, except for a few dots where the plants have discovered inland salt springs or salt lakes, and have found their way to them. Most plants are more adaptable than these, and occupy a variety of habitats. The little Tormentil (*Potentilla silvestris*), for instance, flourishes equally on hot banks by the sea, in woods, and on mountain-tops. The more accommodating a plant is as regards habitat, the wider its distribution tends to be, both locally and in a broader sense. But wide range does not follow of necessity from adaptability to a variety of conditions: the problem of plant distribution is not so simple as that. One species may be spread right round the world, yet be always found in a special habitat; take the case, for instance, of the Yellow

Bird's-nest (*Monotropa Hypopitys*), a strange colourless, leafless plant, highly specialized, feeding, through the intermediary of a minute fungus which infests its roots (see p. 183), on the decaying leaves of deciduous woods in cold temperate regions, and yet found across Europe, Asia, and North America; while many other species, at home under very varied conditions of soil and moisture, have nevertheless a quite restricted geographical range.

Although our own country, favoured by conditions thoroughly suitable to plant life—a sufficiently high temperature and an abundance of moisture and light—is characterized by a continuous plant mantle—or *closed vegetation*, as the botanists say—nevertheless what has been said of desert and semi-desert conditions applies to many limited areas in the British Isles, where the vegetation takes on the peculiar characters of true desert plants. Low water-content and great exposure produce such conditions on shingle beaches and sand dunes; and, as we shall see later, the vegetation of sea-rocks, salt-marshes, and peat-bogs is in many respects analogous to desert vegetation.

Except near the Poles, wherever the precipitation of moisture rises above an amount which varies according to other conditions prevailing, a closed vegetation occupies the ground when the agricultural and other operations of man do not hold it in check. But as much of this favourable region is utilized by the human race for the production of plants used for food or for industry, it often happens, as in our own country, that the natural plant communities are to a great extent destroyed, and can be studied only on

land left undisturbed because unsuitable for cultivation—on heaths and moors, in swamps and lakes, on sea-sands, chalk downs, and so on; and even in most of these places intensive grazing of domesticated animals and other causes connected with human activities alter and control plant life to a greater or less extent, rendering it necessary for us to walk warily in our study of it.

Although the world offers many different aspects of closed vegetation, they may all in a broad sense be reduced to two general types—namely, grasslands and woodlands, the former the result of a lighter, the latter of a heavier, rainfall: grasses and their associates requiring for their life-processes a much less amount of water than a tree vegetation. The British Isles lie within a broad belt that sweeps east and west across Europe, characterized by a prevalence of south-west winds laden with moisture, and yielding a tolerably heavy rainfall distributed throughout the year. South of this belt—south of the Alps, roughly—the rainfall occurs chiefly in winter, and dry summers produce the well-known "Mediterranean climate" with which is associated the scrubby small-leaved vegetation, capable of withstanding heat and drought, which is characteristic of Spain, Italy, Greece, and Northern Africa. Northward, the forest-belt extends into Scandinavia, dwindling into a tundra vegetation of lowly shrubs and herbs as we approach high latitudes with a sub-arctic climate. Forest, then, is the original and natural type of vegetation of the British Islands, and without doubt the greater part of the country was occupied by woodland within the human period. But forest country

is not well suited to human habitation or colonization. The early arts of peace—pastoral and agricultural—called for open ground. To operations of war, also, forests are unfavourable. So it came about that by the use of fire and axe the forests passed away before the march of man, until now we can study only fragments of the original all-prevailing woodland. But it is important to note that certain portions of the British Isles were never, in recent ages, under woodland, and that these mostly preserve still much of their ancient facies. Thus, increase of exposure — a lower temperature and higher wind-velocity—appointed a limit on the hills beyond which trees could not and cannot grow. Wind was and is also responsible for a dwindling of tree growth along the exposed western coastlines. Again, the shallow, porous soil of the chalk downs, very dry in summer, probably never supported woodland, but has pastured sheep since the earliest shepherds fought wolves in Sussex. The scanty soil of Farleton Fell probably never harboured plants larger than the herbs and low shrubs which it now supports; and no doubt the salt-marshes looked the same five thousand years ago as they do to-day, though their positions have changed with each slight alteration in the relative level of land and sea.

To sum up, then, the greater portion of the surface of our country consists of former woodland now reclaimed for the purposes of agriculture, the general aspect of its vegetation altered beyond recognition, though from the fragments left we can still reconstruct with tolerable accuracy its ancient condition, and the flora of which it was composed. In the re-

maining parts, though drainage, grazing, and other human operations have wrought great changes, the face of the country still wears to a large extent its ancient appearance, and the flora is still in the main that which flourished before human activities began to put their impress upon it.

How are we to set about studying this varied vegetation which, in a thousand forms, covers hill and valley? There are several avenues of approach; any one of them, if explored fully, would take us far beyond the limits of the present volume; we shall have to be content with slight venturings along several of them, so as to acquire, in a brief space, as wide a view as we can of the phenomena which our flora displays, and of the problems which it presents.

If we view the vegetation as a whole, we may be tempted to enquire first as to its origin and history. We know that plants have existed on the earth for millions of years, but that the plants of past ages were different from those of the present, just as those of the present will ultimately give place to other forms as yet undreamed of: that the vegetation on which we feast our eyes is, in fact, but the momentary expression of a never-ceasing process of life and change. This is the point of view of the geologist, to whom

> The hills are shadows, and they flow
>   From form to form, and nothing stands;
>   They melt like mist, the solid lands,
> Like clouds they shape themselves and go.

Pursuing this line of enquiry, we may endeavour to trace the descent through the ages of our present plants from bygone types; and coming at length to

the still remote time — as measured by human standards — when the plants which now grow appeared on the Earth's surface, we may try, from a study of their present distribution and of the distribution of their remains in regions where they are no longer found living, to determine their area of origin, and to trace the date and course of the migrations by which they reached our country. In the case of the British Isles, geological considerations play a leading part in such investigations, these islands being but outlying hummocks of a great continental area, at times joined to the main land-mass by a slight upward movement of the Earth's crust, and anon cut off from it by a movement of depression. In this connection also we may be led to investigate the means by which plants spread, and especially their capacity for crossing barriers of the various kinds indicated in our brief study of deserts in the previous pages—the serious barriers offered by water-channels, or others equally difficult to negotiate produced by areas of uncongenial soil, by mountain ranges, or by forests. This will involve especially a study of seeds and the interesting phenomena of seed-dispersal.

Again, the most popular branch of botanical study in England is *Floristic Botany*, which traces the distribution within our area of the various species composing its flora; and with it is necessarily associated a study of the plants themselves so far as the characters are concerned, by which they may be distinguished from each other. This last is the province of *Descriptive Botany*. The study of local distribution, if conducted intelligently, will greatly assist in

solving problems relating to the migrations and routes by which the existing flora reached its habitats.

Once more, we have already from Farleton Fell observed that plants do not grow higgledy-piggledy over the country, but are arranged in more or less definite societies depending on similarity of climate, soil, and other external conditions. Studied from this point of view, the flora resolves itself into a series of communities, each requiring a certain set of conditions for its continued welfare. The study of these inter-relations between plants and their environment, and of the types of vegetation resulting from the grouping together of plants requiring similar conditions, is the province of *Ecological Botany*.

Again, the *morphologist* deals with the forms of the organs of plants, and the changes which these undergo in different plants, while the *anatomist* investigates their minuter structure.

Physiological Botany deals with the life processes of plants, and the way in which they feed and grow and move. It has a very important bearing on the distribution and grouping of plants, since this is largely governed by their food-supply and by the need of surroundings which allow them to carry on their life processes with success.

It will be seen that there are many lines of enquiry open to the student of botany. In the following pages no more can be attempted than the preliminary study of some of the more familiar phenomena of plant life as it presents itself to the holiday-maker on the hills and woods and shores of our own land.

CHAPTER II

PLANT ASSOCIATIONS

"It is perhaps also proper to take into account the situation in which each plant naturally grows or does not grow. For this is an important distinction, and specially characteristic of plants, because they are united to the ground and not free from it like animals."—THEOPHRASTUS : *Enquiry into Plants*, I. iv.

BEFORE setting about discussing the various types of vegetation which our own country presents, it will be well to have a general idea of the extent to which the main types are developed, and of the amount to which agriculture has interfered with the native flora. We have seen that the natural vegetation of the greater part of the British Isles is woodland: yet so profoundly has human industry altered the face of the country that woodland, natural or planted, occupies only about one-twentieth of the surface of England, rather less of Scotland and Wales, and about one-seventieth of Ireland. Much of the former woodland is now represented by "arable land," which covers over one-third of England, and about half that proportion of the other parts of the British Isles. Permanent grassland, partly natural, partly replacing ancient woodland, bulks large in England and Wales, occupying about two-fifths of the whole country; in Scotland and Ireland the proportion is much less, but in those countries a large area is under moor, heath,

or natural grass, over which wander great herds of sheep and cattle. A. G. Tansley* thus contrasts (in percentages) the area of cultivated land (on which natural vegetation has been to all intents destroyed), with the area on which natural or semi-natural conditions still prevail:

	England.	Wales.	Scotland.	Ireland.
Cultivated land	75	59	25	? 20–30
Land under natural or semi-natural vegetation ...	15–20	40	70–75	? 70–80

It will be seen how little of the original vegetation of England is left to us for purposes of study—less than one-fifth, almost the whole of which has been influenced to some degree by human operations; while in Scotland and Ireland a much larger area is more or less in its primitive condition. The Scottish mountain-sides and Irish moorlands still to a great extent retain a natural flora, save that the greater number of grazing animals which they now support, as compared with the times when wolves and other enemies roamed unchecked, leaves its impress upon the vegetation.

Viewing the plant world as a whole, its primary divisions, from the point of view of ecology, are governed by the factor of rainfall. It is true that the plants of the Tropics differ profoundly from those of the Temperate regions, and those again from the plants of the Arctic. But this is a difference in the *species* and families which constitute the vegetation, rather than a difference in the *types of vegetation* or plant formations which occur. A certain area in Siberia may not have one species in common with a certain area in India, but in both we may find the

* "Types of British Vegetation," 1911, p. 63.

three great vegetation types of forest, grassland, and desert. A rainfall gradient, on the other hand, will cause a progressive change in vegetation type, as may be seen in crossing North America from east to west, where the forests of the New England States give way as precipitation diminishes to the prairies of the middle States, and these again to the deserts which stretch far over the west. It is only in the extreme north that temperature, apart from precipitation, becomes the dominant influence in determining the presence or absence of vegetation, or its character.

Within any one climatic region — say within the British Islands—the *soil* in which the plants grow is the controlling factor in determining the character of the plant population. And while a classification by *plant form*—such as woodland, grassland—is often convenient, when we come to analyze the various plant associations which colonize the ground, it will be found that similarity of form-type does not necessarily imply affinity as regards either physiological conditions or floristic constituents. Thus, a Beech wood on the Chalk has really no affinity with an Oak wood on the Coal-measures, save that they are both woods: they shelter plant groups of quite different composition, one a constituent association of the Limestone Formation, and the other of the Formation of Clays and Loams, according to modern English classification. Similarly, the Hazel copse which covers the screes of Farleton Fell has no close relation to the Hazel copses along the Westmorland becks, although the dominant plant—the Hazel—is the same in both cases: soil is the controlling factor,

and the one is related to the limestone vegetation of the hill above, the other to the vegetation of the loams and peaty soils of the adjoining mountain-side. In the British Isles the leading plant formations are those of clays and loams, of sands and sandstones, of siliceous soils, of calcareous soils, of peat, of marsh, of lakes and rivers, of salt-marsh, sand dune, and shingle beach; also, governed by the climatic factor, alpine vegetation stands somewhat apart. While the vegetation of some of these, such as salt-marsh or peat, usually presents a uniform aspect, others, such as the clays, sands, and limy soils, display each a characteristic type of woodland and of grassland, as well as other variants, dependent on the composition, depth, and wetness of the soil, the degree of exposure, and so on: these form the *associations* which together constitute the formation. Each association, if the plants composing it be examined, will be found to consist of an assemblage of species, large and small, brought together by their superior fitness for the particular conditions which prevail. There are mostly in each association one or more dominant species—such as the trees of an Oak wood, or the Heather of a moor—which by their abundance or vigorous growth control the association. The shelter which they give may protect some of the members of the community: the shade which they cast may keep out other plants which otherwise would invade the ground. The association will include some species specially adapted to the particular conditions which prevail, and perhaps not found elsewhere in the area; these are the indicator plants of the association, which give it its special character, and which will

help us to identify the association should we encounter it again; there will be others—dependent species—which are attracted by the shade, or shelter, or other advantages which the growth of the dominant plants affords: and there will be others, again—probably many—of wide distribution, which are merely as much at home here as elsewhere. But all grow here because they are better fitted for the particular conditions prevailing than are the other plants of the surrounding area. On Farleton Fell, for instance, among the most abundant species which fill the crevices of the limestone plateau are two ferns—the Limestone Polypody (*Polypodium Robertianum*) and the Rigid Buckler Fern (*Lastrea rigida*). Though there is rocky ground of many kinds in the Lake District, these two plants are never found save on similar outcrops of the Carboniferous Limestone, and they are clearly specially fitted for life in the hollows of this rock. But the same rock crevices also harbour many species which are found equally on the soils derived from the slate rocks or sandstones. To take another instance: many of our most familiar spring flowers are woodland plants—the Primrose (*Primula acaulis*), Wood Anemone (*A. nemorosa*), Wild Hyacinth (*Endymion non-scriptum*). These rejoice in the humus soil which is formed from the dead leaves of preceding years; they flower before the trees are in full leaf, thus securing plenty of light and air for their period of growth; and they are accustomed to have their stems and roots protected from summer heat by the leafy canopy overhead. Transplanted into an adjoining sunny pasture they will soon die out. They are

characteristic members of the woodland association of one or more formations. But with them we shall find other species, such as the Wild Strawberry (*Fragaria vesca*), which are equally at home on dry sunny banks or even on sand dunes.

If we ask *why* the plants group themselves into the associations which we may study any day in the country, in many cases the answer is not obvious. It is clear that while many species accommodate themselves easily to different soils or different degrees of light or of moisture, others have small powers of accommodation, and are in consequence restricted in their range. By long usage many plants have acquired special characters enabling them to live under special conditions — some examples will be discussed a little later—and in some such cases it is easy to correlate the peculiar characters of the plant with those of the habitat. But in many other cases the relation is not obvious. For instance, we cannot tell, by examining a plant, whether it is partial to a limy or to a non-limy soil; yet many plants are poisoned by lime, while others, though generally capable of growing in a soil devoid of lime (if planted in a garden), are nevertheless absent from the non-calcareous areas adjoining their limestone habitat; in other words, they can hold their own on limestone, but are unable to do so elsewhere. The two ferns already mentioned (*Polypodium Robertianum* and *Lastrea rigida*) are cases of the latter kind; while some of the most familiar of our hillside plants, such as Foxglove (*Digitalis purpurea*) and Broom (*Sarothamnus scoparius*), are instances of the former.

If, however, we consider some of the formations or associations which are the result of extreme conditions of environment, we get more light on the relations between the plants and the factors which control the vegetation. Take the case of the plants inhabiting desert regions such as were discussed in Chapter I. Here the outstanding feature is scarcity of water, and the plants display various remarkable adaptations which fit them for a thirsty life. There are three ways to meet scarcity of water—facilities for gathering it, arrangements for storing it, and economy in using it; and arrangements for all three are familiar features of desert plants. To effect the first, the root-system is extended, and is often enormously developed in proportion to the aerial parts. This adaptation may be studied in the flora of dry places in our own country, such as shingle beaches and sand dunes, which are characteristic semi-deserts. Take such plants as the Sea Holly (*Eryngium maritimum*), the Sea Convolvulus (*C. Soldanella*), or the Sea Sedge (*Carex arenaria*), and compare the extent of the root-system or underground stems with that of the aboveground portions. Fig. 4 represents the Wild Carrot (*Daucus Carota*) as found growing under extreme exposure on the west coast of Ireland. To meet the conditions the tall branched stem has been entirely dispensed with, and the terminal umbel is seated on the ground in the middle of a ring of leaves. In this way the plant prepares to resist both drought and wind. Water storage is often developed in different parts of xerophytes (drought-resisting plants)—in roots, or stems, or leaves, which become much enlarged, and at the same time covered with a

highly impervious skin, so that they act as veritable cisterns. In plants like the Cacti water storage in the stems is carried very far indeed; while in such genera as the Stonecrops (*Sedum*) the leaves are often so swollen and charged with water that they lose up to

FIG. 4.—WILD CARROT (DAUCUS CAROTA), GROWING UNDER GREAT EXPOSURE. ½.

98 per cent. of their weight if they are dried. Prevention of excessive loss of water by transpiration is effected in plants of dry places mainly by reduction in the size of the leaf and by protection of its surface. Leaf reduction is very marked in many dry countries. If we compare the flora of the Mediterranean region

(a dry area) with that of Middle Europe or of England, we shall be struck with the prevalence in the former of small-leaved twiggy plants—Lavender (*Lavandula*) and Rosemary (*Rosmarinus officinalis*) will serve as examples. Often leaf-reduction is carried much farther, and we need not go beyond our own commons to find a good example, for in the Gorse (*Ulex*) flat leaves are entirely absent and the branches are shortened and converted into prickles, thus largely reducing the surface exposed to the sun and wind. The seedling Gorse has little trifoliate leaves, which remind us of its affinity to the Trefoils and Brooms, but they are discarded almost at once, to fit the plant better for life in the dry, breezy localities which it favours. Reverting to the Mediterranean flora, a characteristic of its plants is the prevalence of a grey hue in their stems and leaves, such as we see in the Pinks and Achilleas of our rock gardens. This is due to a coat of wax, as in the Pinks (*Dianthus*), or a felt of hairs, as in the Achilleas, designed to check excessive transpiration. The coatings of hairs are often of great beauty and complexity, and form an almost impenetrable covering to the leaf surface, protecting the upper side from the fierce rays of the sun, and on the underside sheltering the stomata, or minute openings through which the plant exhales the surplus water drawn up from the roots and inhales carbon dioxide. Another very beautiful device for protecting the underside of the leaf, and one which may be studied in many of our commonest plants, consists of the inrolling of the edges, often combined with a wrinkling or ridging of the underside, so that the stomata are set in deep hollows, communicating with

the open air only through narrow openings. The leaves of some of our common grasses show these characteristics to great advantage. And again the stomata are often sunk in little pits, by which device they obtain further protection. If we now examine the plants composing the sand-dune or shingle-beach associations in the light of these facts, we shall find them full of interest. The plants are well equipped to meet the adverse conditions of a very porous soil, drying winds, and scorching sun. Note the grey felt of hairs which protects the leaves of the Horned

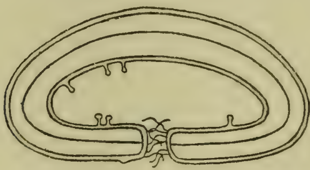


FIG. 5.—SECTION ACROSS INROLLED LEAF OF CROWBERRY (EMPETRUM NIGRUM), MUCH ENLARGED.

Poppy (*Glaucium flavum*), the tough, waxy skin which covers the Sea Holly (*Eryngium maritimum*), the extensive underground stem-systems of the fleshy-leaved Sea Convolvulus (*C. Soldanella*) and Sea Purslane (*Honkenya peploides*). Even the annual plants display similar characters. In the great desert regions the annuals are often quite normal in structure: that is because they appear during the brief rainy season, and pass away before the fierce heat of summer sets in. But on our shingle beaches the annuals grow throughout the summer, and need protection against drought: so the Sea Rocket (*Cakile maritima*), the

Sea Whin (*Salsola kali*), and others are very fleshy plants; their leaves are small, with an impervious skin, their root-systems are better developed than in most annuals. The grasses and sedges of these places, such as the Bent (*Ammophila arenaria*), Sea Wheat-grass (*Triticum junceum*), Sea Sedge (*Carex arenaria*) have underground stems which burrow widely through the sand, with an extensive root-system and tufts of inrolled leaves beautifully protected against over-transpiration, and well worth microscopical examination.

If we turn from the shingle beach to the salt-marsh, where water is very abundant, we shall be struck by the peculiar fact that its vegetation displays characters quite similar to those we have just been studying. How can we reconcile this with the theory that the peculiar characters of the shingle-beach plants are correlated with lack of moisture? The explanation is to be found in the fact that plants have difficulty in absorbing water if it is highly charged with mineral substances in solution. In the salt-marsh the heavy muddy soil is impregnated with common salt (chloride of sodium): the plants absorb it with difficulty; and in consequence they are faced with the same main problem which confronts the Sea Holly and Sea Whin, and they meet it in the same way. Indeed, the salt-marsh plants appear to be more highly specialized, for very few intruders from outside can venture in, while on the beach we may meet with many plants which belong to other formations growing successfully, at least for a time. The salt-marsh flora is very exclusive, and contains but few species which we encounter in other situations. Some of them are also

found on dry sea-rocks — the Sea Pink (*Statice Armeria*), Scurvy-grass (*Cochlearia officinalis*), Sea Aster (*A. Tripolium*), and so on; showing that soaking soil is in no way essential to their growth. (The first two reappear among alpine plants on some of our higher mountains, pointing again to an analogy of conditions not altogether understood.) But the salt-marsh formation as a whole is perhaps the most distinctive as regards its composition of any of the plant-groups of our country. It is dominated by such species as the grey leathery-leaved *Obione portulacoides*, the small-leaved, thick-stemmed Sea Pink, the Sea Wormwood (*Artemisia maritima*), which is all covered with a silky coat; the pools are fringed with *Scirpus Tabernæmontani*, a dwarf greyish copy of the Common Bulrush of our lakes, and filled with the narrow-leaved *Ruppia* and *Zannichellia;* and in the muddiest places are little forests of Glasswort, leafless, very fleshy, the flowers reduced to mere essentials and buried in the fleshy stems (Fig. 2, p. 18).

Again, it is easy to trace the relationship existing between plant form and soil conditions in the bog-land flora; and these relations, unexpectedly enough, turn out to be analogous to those obtaining in the case of the salt-marsh. The sodden peat, sour and badly aerated, and poor in mineral salts, is poor also in the bacteria which feed upon and destroy dead vegetable matter, with the consequence that acid humus compounds collect in the half-decayed vegetable mass; water charged with these substances is as unsuitable for plants as is the water of the salt-marsh. In spite of the wetness of the peat, water is in this case also a desideratum; and the moorland plants, like

those of the sea fringe, possess special adaptations for economizing it. This usually takes prominently the form of a reduction of leaf-surface. The dominant plants, such as the Ling (*Calluna vulgaris*) and Purple Heather (*Erica cinerea*), have minute leaves with reflexed edges and special structure to protect the stomata. The grasses and sedges which abound have similar characteristics; the whole vegetation tends to be small-leaved and long-rooted. A few of the plants, such as the Eyebright (*Euphrasia*), eke out the scanty food-supply by a semi-parisitism, robbing their neighbours of portions of their hardly-won sustenance; one or two others, such as the Bladderwort (*Utricularia*), which floats in the bog-pools, and the Sundew (*Drosera*), which fringes their edges, entrap insects and digest their juices, helping out their scanty rations with an animal diet. On the moors the peculiar soil conditions determine definitely the type of vegetation, which, over large areas, is as uniform and monotonous as that of the salt-marsh.

We see, then, that the peculiar character of several of the most marked of native plant formations—those of shingle, of salt-marsh, and of moor—are due primarily to scarcity of water. They are drought formations, produced either by physical drought, as in the case of shingle, which fails to retain water, or by physiological drought, as in the salt-marsh or bog, where, though water is present in abundance, it is not in a condition in which plants can readily make use of it.

Let us now go to the opposite extreme, and consider the plant formation which characterizes lowland lakes and rivers, where water suitable for plant use is

superabundant. In such places we are faced with a vegetation exhibiting a great number of species and a marked variety of form, and by no means so easy to correlate with its environment as those which we have been considering. In a wide sense, the nature of the vegetation is largely dependent on the degree of aeration of the water and the amount of dissolved mineral salts which it contains, an increase of either (within limits) resulting in a richer flora. But in any one

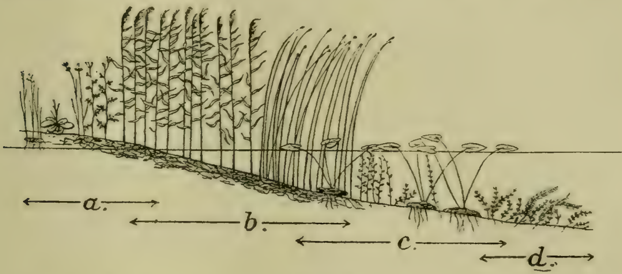


FIG. 6.—DIAGRAM ILLUSTRATING SUCCESSION OF VEGETATION IN LAKES.

a, Marsh zone ; *b*, reed zone ; *c*, zone of floating vegetation ; *d*, zone of submerged vegetation.

area it is clear that depth of water is the controlling factor: the plants are arranged in zones, one succeeding another as the bottom shelves. Two main zones are conspicuous: (1) A zone of tall reed-like plants near the margins, which farther out is succeeded by (2) a zone of lax floating plants which either have leaves resting on the surface or grow entirely submerged. Above the former a belt of marsh plants links the reed zone with the vegetation of the soils of normal moisture; below the latter, should the water

increase in depth, we reach an aquatic desert region, where the reduction of light renders plant growth difficult, and eventually inhibits it. Let us consider the conditions prevailing in the reed zone. Here the plants are essentially aerial, and though they have their feet in water, the stems and leaves rise far above it. Water-level is variable in lakes and rivers; the plants are usually tall, so that even in case of flood the leaves and flowers will not be drowned. Wave action on lake-shores is somewhat violent, and in flooded rivers a strong current may sweep through the vegetation; we see the advantage of the slender elastic stems and narrow leaves that characterize the plants: compare Reed (*Phragmites*), Reed-mace (*Typha*), Flag (*Iris*), Bur-reed (*Spargarium*), Bulrush (*Scirpus*); and these characters also fit them for the windy nature of their habitat. The denuding effect of wave or current action is countered by the network of creeping stems and abundant roots which the plants possess, forming a tough felt which floats, and by its growth and decay helps materially to form fresh land. Another effect of the creeping and branching stem-systems is the production of extensive and dense groves of many of the species.

When we pass beyond the reed zone, a completely different type of vegetation prevails. Here the plants are essentially aquatic. They make no effort to raise their stems and leaves above the water surface; but almost all of them raise their flowers into the air, though the seed is often ripened below the surface by a downward curving of the stem. These plants, surrounded by water, use their roots chiefly as anchors, and absorb through their stems and leaves the water

from which they obtain the necessary mineral salts. As regards the supply of oxygen and carbon dioxide which the air supplies to them, thōse with floating leaves absorb it from the atmosphere, while those whose leaves are submerged have to subsist on the small quantity of these gases which is dissolved in the water—no wonder that such plants are rare in stagnant waters where aeration is poor. To assist respiration and transpiration, abundant and often comparatively gigantic air-spaces are provided in roots or stems or leaves, giving them a cellular appearance, and making them singularly light and spongy in texture. The leaf system of those plants which possess floating leaves—such as Water Lily (*Castalia* and *Nymphæa*) or Common Pondweed (*Potamogeton natans*), are well worth study. They are tough, to withstand battering by waves; the stomata are situated, not on the lower side of the leaf, as in land plants, but on the upper side, where they are in contact with the atmosphere; and the upper surface is waxy or oily, so that it is not wetted and the stomata are not blocked. Changes of water-level are met by means of long flexible stems, rising not vertically from the root, but at an angle, so that the leaves can rise with a rise of water-level. But not all the plants are anchored to the bottom. Some, which favour especially ditches and quiet waters, float freely with roots hanging down in the water—the Frog-bit (*Hydrocharis*) and Duckweeds (*Lemna*) are familiar examples. In the Duckweeds true leaves are absent, but the tiny stems are flattened and green and serve the same purpose, the minute flowers being borne on their edges. A few plants, such as the smallest of the

Duckweeds (*Wolffia arrhiza*) and the Bladderworts (*Utricularia*), have gone farther still, and have dispensed with roots altogether. In *Wolffia*, indeed, the degeneracy of structure which results from the simplification of life problems in plants which live thus floating freely in water, is carried to its extreme limit. Leafless, rootless, and almost flowerless, it maintains itself by the budding of its tiny green fronds, a life-history as primitive as that of the lowly Algæ among which it lives. In the Bladderworts, the long flaccid stems, clothed with much-divided leaves converted in part into ingenious insect-traps (see p. 188), hang limply in the water, sending up boldly into the air their flowering shoots with yellow Snapdragon-like blossoms. In most of such free-floating plants, compact buds are formed at the tips of the shoots in autumn, and while the rest of the stem dies away these sink to the bottom and remain there safe from frost and storm until the spring, when they rise to the surface and produce a new crop of plants.

We have now glanced at the most distinctive of the plant formations which we meet with in our own country, and find that they accompany extreme conditions relating to water and soil: it remains to return to the consideration of the vegetation which develops under conditions of a more normal character—on ordinary soils, in fact, which are neither very wet nor very dry. Such conditions are precisely those which are required for agricultural purposes; and over the wide areas where they prevail, we find, as pointed out already, mere fragments of the native associations remaining in an undisturbed condition. This renders their study more difficult, and the diffi-

culty is heightened by the fact that while the physical conditions show no contrasts so marked as those which we have been considering, the formations which can be distinguished are several, and each contains several associations—often a woodland, a scrub, and a grassland type. Thus, the formation which occupies calcareous soils exhibits characteristic woodlands—woods of Ash (*Fraxinus excelsior*), for instance, and on the downs peculiar woods or scrub of Box (*Buxus sempervirens*), Juniper (*Juniperus communis*), Yew (*Taxus baccata*), or Hazel, as on Farleton Fell. It also bears some very marked types of grassland, as on the chalk downs; and the limestone pavement of Farleton Fell is a special variant of this. Similarly, clays and loams, sands, and siliceous soils possess similar characteristic types of vegetation. But the consideration of these would occupy more space and lead us into more technical detail than the scope of this book warrants. For an account of these associations, written by botanists who have made a special study of them, the reader is referred to Tansley's "Types of British Vegetation."

CHAPTER III

PLANT MIGRATION

All organisms, animal as well as vegetable, are at some period of their existence provided with an opportunity of migration. In the animal world, most land creatures have legs or wings, which allow them to roam about freely—a freedom which is of special importance as enabling them to obtain nourishment and to avoid disadvantageous conditions. Aquatic animals are likewise to a great extent possessed of powers of locomotion, but such powers are not so essential to them as to terrestrial creatures, since the water itself is full of small organisms, both animal and vegetable, on which they can feed; hence a large variety of water creatures are content to remain during much of their lives fixed to one spot, extracting from the water as it passes by both the supply of organic food and the inorganic substances, such as oxygen or carbonate of lime, which they require for their life processes. These sedentary creatures, of which barnacles, sea-anemones, and zoophytes will serve as examples, once attached, do not move from the spot where they have settled down; but it is important to note that not only are their eggs or young mostly liberated into the water, and by it transported to new homes, but in their juvenile stages they often swim vigorously, and thus achieve a wide dispersal.

In the plant world, the higher forms, with very few exceptions, spend their lives attached to one spot, like sea-anemones, deriving their food-supply from the air and from the soil; but they similarly are given the opportunity, after birth, of migrating. In our familiar wild flowers, for instance, the young plant, at an early stage of its existence, while it is still minute, becomes covered with a coat often of very resistant qualities, and is then cast loose by the parent in the form of *seed*, mostly in great numbers, to achieve what travels it can before it takes root and settles down, like its parent before it, to a humdrum existence. In the Cryptogams, or so-called Flowerless Plants, this temporary compression of the organism into very narrow limits suitable for easy dispersal takes place at a different period in the life cycle, but for mechanical purposes the results are similar. Minute bodies, or *spores* (much smaller than the seeds of the Seed Plants), are cast loose by the parent often in vast numbers, and eventually settle down and reproduce the species. In many of the lower aquatic plants these spores are provided with means of locomotion in the form of a tail-like appendage, which by its movement propels the germs through the water, giving them the same advantage which is possessed by the young of many of the sedentary animals.

The opportunity for migration thus offered to sedentary plants once at least in each cycle is of very great importance. A plant, living on one spot and drawing, from that portion of the soil which its roots can reach, certain mineral salts essential for its continued growth, tends to exhaust the available supply of these materials, and the succeeding generation

needs to reach fresh ground if it in turn is to attain healthy development. And it is undoubtedly of advantage to plants, if they are to continue to exist on the Earth, to be able to jump barriers and to colonize fresh suitable habitats which may arise in the course of natural changes, which sooner or later may render old habitats untenable. Thus the very existence of plants upon the Earth depends on the adequacy of seed-dispersal. This being so, the imaginative mind, viewing the marvellous and infinitely varied contrivances of Nature, will possibly be struck more by the want of special provision for dispersal shown by the majority of the higher plants—their helplessness in this respect—than by the beautiful devices exhibited by the few. In the first place, seeds are inert, devoid of any power of locomotion—though in some instances the last act of the parent is to discharge them with an explosive action into the air. They are dependent on the movements of external media—air, or water, or wandering animals—for transportation of any magnitude, and while many possess very beautiful devices for enabling them to take advantage of opportunities in this regard, the majority are devoid of any special structures. They are as inert as pebbles or grains of sand: but they possess two attributes which form important assets — namely, numbers and vitality. The amount of seed produced annually is hundreds, or more usually thousands, sometimes hundreds of thousands, for each parent. What matter if myriads perish? If one in so many thousands takes root and grows, the species will not diminish in numbers. Vitality also largely affects the problem. The seed can endure extremes of heat and

cold which would be fatal to the parent; it can be drowned, or scorched, or dashed about, or in many cases eaten by animals without injury; it can lie buried in the soil for a long period of years, yet if turned up again and placed within reach of the requisite amount of air and heat, will spring up vigorously.

As a matter of fact, investigation soon shows that absence of special devices for dispersal provides no measure of the breadth of a plant's distribution, nor is profuse seed-production necessarily related to abundance of offspring. Many factors come into play, and conclusions of this obvious kind will generally only lead us astray. But that does not render the study of each one of the factors less interesting.

This matter of seed-dispersal is of prime importance in our study of familiar British plantscapes, for our vegetation is the expression of the past and present efficiency of its particular rôle in the ever-changing drama of Nature. We shall do well to spend a little time in considering it.

First of all, as to the nature of the seeds with which we have to deal. These are, as already pointed out, young plants, already a long way advanced from the egg stage, neatly tucked up and enclosed, in most cases along with a supply of food material, in a tight, strong skin, which is mostly of a particularly impervious character, protecting the young plant from injury by bruising, from attacks of small animal enemies, from extremes of heat and cold, of moisture and dryness. The young plant, too, is in a peculiarly resistant physiological condition. For instance, its breathing—or absorption of oxygen—is exceedingly slow, and it is

not suffocated by burial, sometimes even for years, in the soil. And while the mature plant is killed instantly by immersion in boiling water or by exposure to a very low temperature, some seeds, if boiled for a quarter of an hour, are quite uninjured, while others, subjected experimentally to even the temperature of liquid hydrogen (– 260° C., or 436 degrees of frost on our more familiar Fahrenheit scale), remain unaffected. Many seeds are liberated from the parent plant enclosed by or attached to appendages of various sorts (when they are called by the botanist *fruits*) which sometimes greatly aid dispersal, as in the Dandelion (*Taraxacum*), and sometimes appear to hinder it; in any case, while the young plant itself is usually quite small, it may, when surrounded by its food-supply and enclosed in its wrappings, be a bulky object—as is seen in the Cocoanut or Horse Chestnut. In the British flora, to which we may confine our attention, a crab-apple (containing a number of seeds), a hazelnut, and an acorn (each containing a single seed), are the largest *units of dispersal* with which we have to deal. But these are quite exceptional in size, and the average seed (using that term in its original sense of the natural unit of dispersal) in the British flora does not exceed the size of a pin's head. This remarkable reduction of size alone aids dispersal greatly.

The migrations of plants are effected mainly during the seed stage, these tiny, tightly packed portmanteaux being much better fitted for travel than the bulky and fragile organisms to which they give rise. But before we consider the adventures of seeds it must be pointed out that a considerable, if slow,

migration of plants takes place by mere vegetative growth. The stems of many species are not erect, but prostrate; creeping upon or below the ground, they may in time cause a plant to spread far beyond its place of origin. A whole field, or for that matter a whole hillside, of Bracken (*Pteris Aquilina*) may quite possibly have originated from a single wind-borne spore. Among Sedges and Grasses this mode of growth is common—as we know to our cost in the case of the Couch-grass (*Triticum repens*)—and it is found in varying form in many kinds of plants, as in the suckers of trees, the offsets of bulbs, the runners of the Strawberry (*Fragaria*); it is especially characteristic of marsh and water plants. Its effect is to produce large colonies, such as the great beds of Reeds (*Phragmites*) or Reed-mace (*Typha*) which fringe our lakes, the groves of Bent (*Ammophila*) on sand dunes, and the beds of Anemones (*A. nemorosa*) or Broad-leaved Garlic (*Allium ursinum*) of our spring woods. In all these cases the whole colony *may* be the result of the continued growth of a single individual. It should be noted, however, that such migration is possible only so far as favourable soil conditions extend. A slight barrier—a streamlet, a patch of ground too wet or too dry, will arrest further progress, and the plant must fall back on seed-dispersal in order to conquer further territory.

A vegetative device which, so far as its method and value in dispersal are concerned, approaches those of seeds, is found in the bulbils with which some plants are furnished. These are small buds—congested shoots—borne on stems, or on leaves as in the Lady's Smock (*Cardamine pratensis*), or among the

flowers as in many Leeks (*Allium spp.*). These usually fall from the parent when mature, and being comparatively small and possessed of considerable

FIG. 7.—CORAL ROOT (DENTARIA BULBIFERA).
a, Upper half of shoot, $\frac{1}{2}$; *b*, creeping stem, $\frac{1}{2}$; *c*, bulbil, $\frac{2}{1}$.

vitality, they may achieve a considerable dispersal before they send out roots and fasten themselves to the soil. An example is figured (Fig. 7). In this plant (*Dentaria bulbifera*, the Coral Root, a rather

rare native of England) the bulbils resemble not the smooth flower-stems of which they are axillary branches, but the curiously knobby underground stems from which the leaves and flowering shoots arise.

Since seeds themselves possess, as already stated, no power of locomotion, they have to rely on external agents for their dispersal. These may in general be summed up as (1) Action of the parent plant, (2) water, (3) wind, (4) animals.

1. *Action of the Parent.*—The Ivy-leaved Toad-flax, or Mother-of-Thousands (*Linaria Cymbalaria*), is a pretty little plant, native in central and southern Europe, naturalized and common on old walls in this country. Its Snapdragon-shaped purple flowers are borne on short stalks which curve towards the light, placing the blossoms in a conspicuous position, where they may be the more readily visited by insects, and thus pollinated. But when flowering is over, and the little round fruit is ripening, the stalk twists so that the fruit is turned towards the wall and finally pushed into any convenient crevice: when the capsule opens, the seeds, instead of dropping to the base of the wall where on germination the young plants would be smothered among stronger growths, find themselves lodged in niches in which the young plants may develop successfully. Many water plants have flowers which rise into the air, following on which the flower-stem curves and the seed is ripened below the surface, free from the dangers of weather, of feeding water birds, and so on.

A very common type is that in which the seed-vessel opens at the top when the seed is mature. Gusts of

wind, or passing animals, bending the stem, cause the latter to spring back, casting the seeds out. When the seed-vessel opens widely, as in the Columbine (*Aquilegia*), the seeds may be cast to some small distance. The efficacy of the arrangement is not so obvious when, as in the Poppies (*Papaver*) or Bell-

FIG. 8.—FRUIT OF GIANT BELL-FLOWER (CAMPANULA LATIFOLIA). ¾.

flowers (*Campanula*), the openings are small (Fig. 8), but it is clear that these plants do not suffer from lack of dispersal, in view of their abundance and wide range.

But the assistance which the parent plant gives is often of a more active and even dramatic character, though in these cases it is usually effected not by a

movement of living tissue as in the last case, but by mechanical changes taking place in tissues already dead or dying. If we stand by a bank of Gorse (*Ulex*) on a warm day we may become aware of a snapping sound, and may possibly feel on our faces the impact of small bodies. These are gorse seeds in process of being distributed by the parent. In this shrub the fragrant flowers are succeeded by short tough, hairy pods, formed of two valves joined together by their edges. (In reality the pod is a modified leaf folded down the middle, the two edges thus brought together being joined—see p. 129.) When the seed is ripe the pod dries, and owing to unequal shrinkage of the valves stresses are set up which at last tear the pod suddenly asunder along its edges, flinging the seeds violently out into new ground, where they will have a better chance of life than if merely dropped into the middle of the parent bush. A similar arrangement is found in the Vetches and many other Leguminosæ. In the Cranesbills (*Geranium*) a very ingenious catapult device may be examined. The fruit is of peculiar structure. We might make a rough model of it by taking five single-sticks and tying them to a broom-handle—firmly at the points, less securely elsewhere—and slipping a tennis-ball into each basketwork hand-guard before turning its open side in against the broom-stick, so that the ball cannot fall out. Imagine now that unequal drying on the part of the sticks tends to make each bend into a semicircular form, which is hindered by the fastenings at either end. The stress will eventually tear the weak fastenings at the base: the lower end will fly up, bearing with it the ball (representing the seed), which will be projected

out through the open side. In the Cranesbills the jerk is so violent that seeds may be flung to a distance of twenty feet. One of the most efficient of all devices of this kind is found in the Sand-box Tree (*Hura crepitans*), a native of South America. By sudden rupture and twisting of the carpels of the woody sub-globular fruit, the large seeds of this plant are thrown

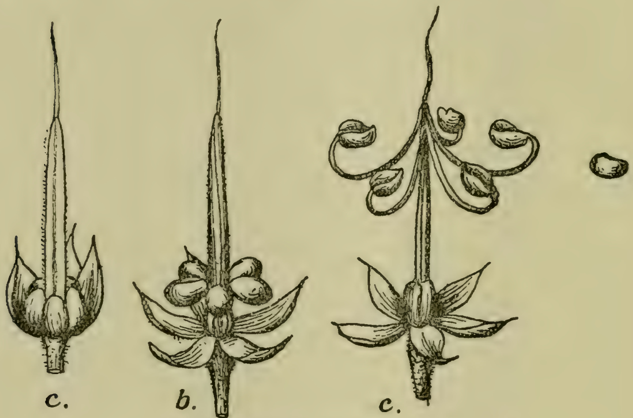


FIG. 9.—FRUIT OF GERANIUM.

a, Mature; *b*, ditto, with pouches raised ready to discharge nuts; *c*, in act of discharging.

to a distance of thirty yards, the explosion being accompanied by a report like that of a pistol-shot. In the common Dog Violet (*Viola Riviniana*) (Fig. 10) the fruit is a three-valved capsule, which on ripening divides; each valve assumes a horizontal position and its edges contract till it is shaped like an open boat, the seeds lying in a row down the middle. The sides as they dry close in tighter and tighter on the seeds,

which are in turn pinched out, and fly off with a little snap to a distance of many feet. It is an interesting experience to watch these tricks of Nature—much more interesting than merely to read about them. If plants of Vetch, Gorse, Dog Violet, Storksbill, Wood Sorrel, Touch-me-not (to name a few), bearing unripe fruit, be brought home and placed in water in a sitting-room, the click of the bursting fruits will be distinctly audible, and by spreading a white sheet the efficiency of the devices may be tested.

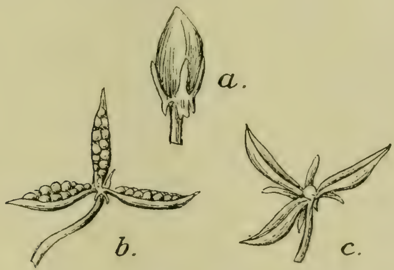
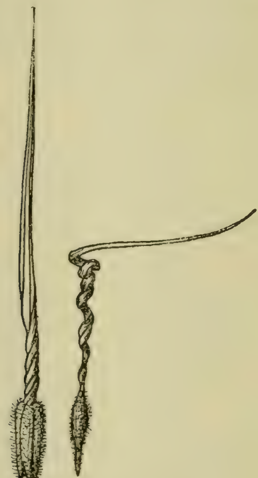


FIG. 10.—FRUIT OF VIOLA. $\frac{3}{4}$.

a, Mature capsule ; *b*, capsule open ready to discharge seeds ; *c*, capsule after seeds are discharged.

A very interesting case, in which the seed is actually buried in the soil by movements of its appendages (portions of the parent plant which remain attached to it), may be watched in the case of the Storksbills (*Erodium*), several species of which are British plants of frequent occurrence. Here the young fruit much resembles that of its allies the Cranesbills. The long rod-like axis at the lower end of which the seed is enclosed contracts unequally in drying, so that the upper half assumes a position at right angles to that of the

lower half, which when dry is much twisted, like a rope (Fig. 11). The covering of the seed itself is furnished with stiff short hairs pointing upwards. The whole structure when mature is cast off by the parent. The curiously twisted appendage is hygroscopic, and readily responds to wetness by untwisting and to dry-



a. *b.*

FIG. 11.—FRUIT OF STORKSBILL (ERODIUM). $\frac{2}{3}$.
a, Mature, twisting beginning ; *b*, separate fruit, fully twisted.

ness by twisting. Should it be thus caused to untwist when the upper end is free from obstruction the latter will revolve slowly like the hand of a clock. But should it meet with an obstacle in the course of its revolutions, such as a blade of grass, the motion is transferred to the lower end, which revolves like an

auger, and, lengthening as it untwists, forces the seed into the ground. Should dryness supervene, the backward-pointing hairs on the seed-envelope prevent its being drawn out again when retwisting and consequent shortening take place. These *Erodium* fruits are among the most interesting in the British flora, and are well worth experimenting with.

2. *Water.*—Water, which forms the most frequent and the most serious barrier to plant migration, under certain circumstances is a very efficient agent of dispersal. At the same time, its powers in the latter direction are strictly circumscribed. As regards fresh water, seeds which float may be wafted across lakes. Rivers are more effectual, as seeds may be transported long distances in their currents and thrown up finally on their banks or over flooded areas. When we consider the sea, we realize that there is here a possibility of almost unlimited dispersal provided that the seeds are not injured by salt water, and that they can remain afloat. It is on the latter point that the whole efficacy of water dispersal turns. This was long ago recognized, and investigations have been made by many naturalists to determine the buoyancy of seeds of all kinds. The results show that, taking the seeds of the plants of any country as a whole, not more than about 10 per cent. are capable of floating for more than a short period, while most of them sink at once in either fresh or salt water. So one's vision of seeds transported in myriads over hundreds of miles of sea is rudely dispelled; and the fact that many seeds can survive prolonged immersion in sea-water uninjured is of little account. The 10 per cent. of our own flora which produce buoyant seeds are mainly

riverside and seaside plants; and no doubt their dispersal is to a great extent due to streams and tidal currents. But the majority of the hundreds of thousands of seeds which a river transports annually find their last resting-place in quiet backwaters or on the floor of the sea.

It is different, however, with the flora which fringes beaches in the Tropics. Here many of the plants possess large fruits of great buoyancy, which are still afloat and alive after months of tossing on the waves, and if cast up germinate readily. These bold wanderers are a familiar feature of Tropic plant life, and their successful voyaging accounts for the uniformity of the beach flora on innumerable islands. Even our own inhospitable shores sometimes receive these waifs of warmer seas, brought from the West Indies by the Gulf Stream and the prevailing southwest winds. Of these the most frequent are the large bean-like seeds of *Entada scandens*, a Leguminous plant, which are originally enclosed in gigantic pods several feet in length, and the more globular seeds of the Bonduc (*Guilandina bonducella*), another species of the same order. But the most famous of all floating fruits is the Double Cocoanut, or Coco-de-mer, a huge nut weighing 40 or 50 lb. and containing several seeds a foot and a half long. It is the product of a Palm (*Lodoicea Sechellarum*); cast up on the shores of India, it was known centuries before its place of origin in the Seychelles was discovered, and fantastic legends grew up regarding it.

3. *Wind*.—Everything that we know about the wind suggests that it is a potent agent of seed-dispersal, far excelling, for instance, that of flowing water. "All

the rivers flow into the sea," that cemetery of seeds, and their courses are at best mere spider-lines on a map. But the wind, blowing where it listeth, is everywhere, always ready to snatch up in its arms any seed of sufficient lightness, and to bear it away from the parent; in fancy we can see tiny seeds borne by gales across mountains and oceans. But we have to leave imagination out of account, and examine prosaically the mechanical laws according to which such transport is of necessity conducted. Any body liberated in still air will fall vertically with a velocity which increases according to well-known laws until the increasing resistance of the air to its passage equals the effect due to gravity; it thenceforward continues to fall at a uniform velocity, that velocity depending upon the nature of the falling body. In all seeds which are sufficiently light to be at all suitable for wind dispersal, the resistance of the air almost at once counteracts acceleration due to gravity, so that the rate of fall may be taken as uniform from the beginning. If the seed on liberation is carried along by the wind, it will acquire almost immediately the horizontal velocity of the air-current, but it will at the same time move downward through the air with the same velocity as if the air was still—just as a body dropped in a railway carriage will fall at the same rate whether the train is moving or standing still. If we measure the speed of fall of a seed in still air, then we can easily deduce the distance to which it will be carried by a horizontal air-current of given velocity if liberated at any given height above the ground. Thus, if a seed liberated 100 feet from the ground falls that distance in half a minute, and the wind is blowing at

the rate of, say, 1,000 feet in half a minute (or nearly 23 miles per hour, a good breeze), the seed will be carried 1,000 feet before it reaches the ground. Its course will be represented by the diagonal AD of the accompanying figure, where AB represents the distance which the seed falls in the given time, and AC the distance according to the same scale travelled by the wind in the same period.

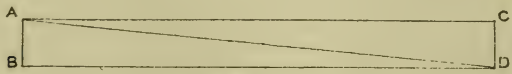


FIG. 12.

But most seeds sufficiently light to be capable of extended flights are liberated only a few feet from the ground; they are dependent on upward eddies to raise them if they are to achieve more than a very short migration. That such eddies, both upward and downward, occur on a windy day we all know from experience; and it is they that make or mar the fortune of most wind-borne seeds. Only some local or accidental excess of upward over downward eddies will assist a seed on its journey; and as every upward eddy must be compensated somewhere by a downward eddy, the longer the journey is, the more such eddies tend to neutralize each other. Over the sea—that most formidable barrier to plant migration—eddies do not prevail as they do over rough ground, so that, unless by a series of lucky eddies a seed is whirled up to a considerable elevation before it leaves the shore, the chances of its successful passage across a stretch of water are remote. Discussing the possibility of seeds of Portuguese plants reaching the

Azores, lying 800 miles to the westward, H. B. Guppy* shows, from observations on the rate of fall of seeds made by several workers, that with a 50 miles per hour horizontal wind the light-plumed seed of the Common Groundsel (*Senecio vulgaris*), for instance, would require to be liberated at a height of 9 miles above the ground if it is to reach the islands: or to express it differently, if liberated at ground-level, the seed would need to be raised 9 miles by upward eddies during its journey, even if corresponding downward eddies were absent—which they certainly never are. It is clear that if even light seeds are to achieve anything more than short journeys, they must depend on exceptional disturbances of the air, such as whirlwinds and tornadoes.

It is now time to examine the devices by which many seeds achieve a more or less wide dispersal by means of the wind. Seeds possessing these adaptations may be divided into three classes: (i.) Powder seeds, (ii.) winged seeds, (iii.) plumed seeds.

By powder seeds are meant seeds of very small dimensions. Reduction in size, if carried far enough, greatly facilitates dispersal by wind. This is because the resistance offered by the air is relatively greater for a smaller body than for a larger one, so that rate of fall decreases as the size of the falling body diminishes—we all know how even a heavy material, if reduced to powder, will fall more slowly than when forming a single mass. Most of the spores of the "Flowerless Plants"—Ferns, Mosses, Fungi, etc.—are exceedingly minute, and have as a result a very slow

* H. B. Guppy: "Plants, Seeds, and Currents in the West Indies and Azores," 1917, p. 425.

rate of fall, and a consequent power of long-distance dispersal by wind. For instance, the microscopic spore of the puff-ball *Lycoperdon* falls so slowly that, if we take again Guppy's Azores example, it could traverse the 800 miles in a 50 miles an hour gale if it commenced its flight only 86 feet above the ground. Such spores are, in fact, so buoyant that they form a normal constituent of the air—as we know, for instance, by the rapidity with which they will discover and germinate upon a piece of cheese, forming bluemould—and with little doubt they are capable of reaching under favourable circumstances the most distant of oceanic islands. But in the Flowering Plants with which we are mainly concerned reduction in size is not carried far enough to confer any great amount of buoyancy. The minute seeds of the Poppies (*Papaver*), for instance, fall about 10 feet in a second. Applying again Guppy's Azorean case, we find that though these would cover the distance in sixteen hours, they would fall in that time about 100 miles, unless raised during the journey to that extent by the excess of upward eddies as compared with downward ones—a quite impracticable proposition. In the Orchids alone do we find among the powder-seeded Flowering Plants a really effective buoyancy; this is due to the fact that great reduction in size is accompanied by very loosely disposed tissue enclosing the seed in a kind of net, and by the resistance to the air thus offered, greatly reducing the rate of fall. The seed of the Marsh Helleborine (*Epipactis longifolia*) falls only about $\frac{1}{15}$ as fast as that of the Poppies, and would thus, under the same conditions, be carried fifteen times as far.

To pass on. Some seeds, many of them of considerable size as compared with those which we have just considered, have coverings which are furnished with a membranous wing (Fig. 13, *d*), sometimes extending all round the seed, as in the Elm (*Ulmus*), more often placed at one side, as in the Sycamore (*Acer*). The effect of such wings is to reduce the rate of fall, imparting to the seed an irregular zigzag motion, as in the former case, or a spinning motion as in the latter. A Sycamore seed with the wing removed will fall four or five times as fast as with the wing present. But while a well-developed wing forms a more efficient dispersal device than mere reduction in size as found in Seed Plants, the rate of fall of wing seeds as a whole shows that these appendages do not fit them for anything but short voyages.

We may then pass on to consider the plumed seeds, which possess by far the most efficient as well as the most beautiful devices for aiding dispersal found among wind-borne seeds. These plumed seeds belong to many different groups of plants, and the tufts of delicate hairs which give them their buoyancy arise in different ways. Among the *Compositæ*, the Order which furnishes the most familiar of our plumed seeds, the plume is formed by modification of the upper part of the calyx, which in so many common plants is small, green, and leaf-like; the lower part of the calyx in the *Compositæ* is tough, persistent, and close-fitting, forming an additional protection for the seed. The plume springs either from the top of the seed, as in the Thistle, or is borne on a slender stalk, as in the Dandelion. It consists of a ring or radiating mass of hairs of beautiful delicacy, often bearing short

branches; these hairs are tightly packed together when the fruit is young or during damp weather, but on a dry day when it is ripe they spread out, and the seed, breaking away from its attachment, is floated off by the wind. In many species the plume or *pappus* is only lightly attached to the seed, so that if

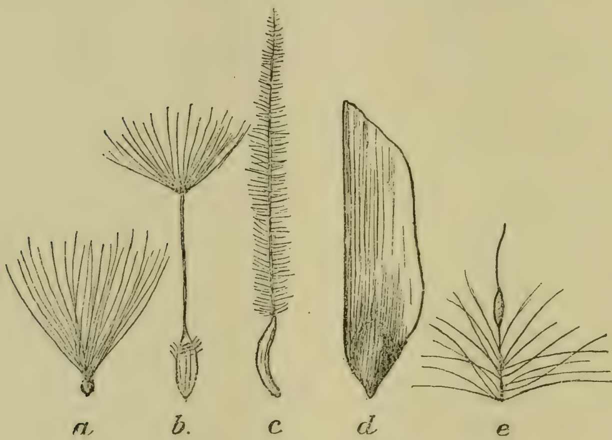


FIG. 13.—WING-SEEDS AND PLUME-SEEDS.

a, Mountain Willowherb (*Epilobium montanum*), $\frac{2}{1}$; *b*, Dandelion (*Taraxacum officinale*), $\frac{2}{1}$; *c*, Mountain Avens (*Dryas octopetala*), $\frac{1}{1}$; *d*, Scotch Fir (*Pinus sylvestris*), $\frac{2}{1}$; *e*, Reed-mace (*Typha latifolia*), $\frac{2}{1}$.

on a voyage an obstacle is encountered the seed drops off, while the now useless parachute drifts away. But though the plume seeds of the *Compositæ* are the largest and most beautiful among our common plants, they are not the most efficient for dispersal. The fluffy seeds of the Willowherbs (*Epilobium*) and of the Willows (*Salix*), for instance, fall at a slower rate than

those of almost any *Compositæ*, while by far the most buoyant seed in the British flora is that of the Reed-mace (*Typha*). In this case the seed itself is minute, and is situated on a very slender stalk, from near the base of which springs a tuft of delicate hairs. This seed takes thirty-four seconds to fall twelve feet. Using once more the Azorean example, it could cross the 800 miles of sea if it had an initial elevation of 3⅓ miles, or was raised to that amount during the sixteen hours occupied by its passage.

Summing up, then, we find that the plume seeds are the most efficient of all seeds for extended flights by the agency of the wind. If the efficiency of the seeds of the Reed-mace, the most buoyant among British plants, be taken as 100, the efficiency of the Willow-herbs is between 60 and 70, of Willows 45 to 70, the best of the Thistles 35 to 40, Dandelion 25. Even the best of the winged seeds are much less efficient, Elm and Scotch Fir being about 20, Sycamore and Ash 9 or 10. Of powder seeds, the efficiency of several Orchids tested ranges from 35 to 65, and Broomrapes (*Orobanche*) from 20 to 25. Most of the powder seeds are far below these, the efficiency of seeds of *Papaver dubium*, for example, being only 4·5 on the same scale. This last figure is representative of the many small-seeded plants in the British flora such as are found among the *Cruciferæ*, *Caryophyllaceæ*, *Scrophulariaceæ*, etc. The relative efficiency of such comparatively large seeds as those of many of our Leguminous plants would be about 1 on the same scale.

4. *Dispersal by Animals*.—The coverings of many seeds are provided with hooks or barbs, and others with stiff hairs, which render them liable to become

entangled in the hair or fur of passing animals. Examples will occur at once to the reader, as this character occurs in the case of many familiar plants, such as Burdock (*Arctium*), Enchanter's Nightshade (*Circæa*), Avens (*Geum*), and so on. Without doubt these hooked fruits often secure a wide local dispersal by the aid of cattle, sheep, rabbits, and so on: the state of one's trousers or stockings after walking the autumn woods is often very suggestive in this regard. Again, herbivorous quadrupeds eat seeds in quantities, many of which are capable of germination after passing through the animal's body. But while the dispersal obtained by such means may often aid in spreading a species over a tract of land, it does not generally aid in the crossing of barriers, such as mountains or sea, on account of the limitations to the movements of such animals. To arrive at a true estimate of the importance of the animal kingdom in regard to plant migration, we have to study the movements, habits, and food of birds, to whose wanderings neither mountains nor seas set a barrier. Seeds are carried about by birds in two ways—by becoming attached to their feathers or feet, or by being eaten and subsequently ejected. The first case belongs to the class of phenomena which we have just been considering, save that the smooth plumage of birds, and their frequent preening of their feathers, tends to keep their coats free from extraneous material. But at least in wet weather minute seeds must often cling to feathers and to feet, and mud which may contain seeds may easily be present on a bird's toes during flight. More important is the question of *endozoic* dispersal—where seeds are trans-

ported in the alimentary canal of birds. Some families, like the Finches and Tits, which eat great numbers of seeds, are inimical instead of helpful to dispersal, because the seeds which they devour are crushed and afterwards digested. But in many cases the seeds are swallowed whole, and are usually in no way injured by their passage through a bird's body. Frequently, indeed, the seeds have not to run the gauntlet of the digestive juices of the alimentary canal, being disgorged from the stomach along with other hard material prior to digestion. Birds which live on berries or other juicy fruits are the most important in seed-dispersal. As Barrows says: "The seed-eaters are not the seed-planters; on the contrary, the insectivorous birds more often sow seeds than the true seed-eaters." "Seeds which *simply contain* nourishment are eaten and destroyed, while seeds which *are contained in nourishment* are eaten and survive."* It is for this reason that, if we look under a tree on which Blackbirds or Thrushes perch, we shall often find young plants of Bramble (*Rubus*), Ivy (*Hedera*), Holly (*Ilex*), or Yew (*Taxus*). There can be no doubt that birds eat and subsequently eject vast numbers of seeds still capable of germination; many observations and calculations might be quoted. But when we come to apply the facts to the problem of long-distance dispersal, or the passage across serious barriers, we find that important limiting factors must be taken into account. The digestion of birds is remarkably rapid, food being ejected from a half to three hours after being eaten, so that a bird eating

* W. B. Barrows: "Seed-planting by Birds." Report of the Secretary of Agriculture, U.S.A., 1890, p. 281.

seeds and at once flying off in a straight line at, say, 50 miles per hour could not convey seeds more than 150 miles. Secondly, many observations show that on migration birds generally travel with empty stomachs and clean plumage and feet. It is clear, therefore, that, as in the case of wind dispersal, we must look to exceptional circumstances, not normal conditions, to provide opportunities for long journeys on the part of seeds. But for the transfer of seeds from France to England, for instance, or from England to Ireland, it is clear that birds furnish a far more efficient medium than wind or water. In one important particular, dispersal by animals has a great advantage over dispersal by wind—that it is practically independent of the weight of the seeds. Thus, the heaviest of British seeds, the acorn, is carried about by Rooks, just as the hazelnut is scattered by Squirrels, or a head of Burdock fruits by a passing sheep.

Having thus arrived at some idea of the high efficiency for dispersal of many kinds of seeds, it is with some little surprise that we observe—as we may on any country walk—that the plants which arise from these are in general no more abundant or more widely distributed than others which possess seeds devoid of any apparent advantages in this respect—seeds which cannot fly nor float, nor cling to a passing creature, and which are not eaten to any extent by birds so far as observation goes. The truth is, we have to remember, as emphasized in a previous chapter, that the world is already densely populated by plants, all of which survive by reason of their being specially fitted for their several habitats. They have

fought in the great struggle for existence, and have established their right to the places which they occupy; they will not readily give way to any newcomer whose seeds happen to be imported into their strongholds. Of course exceptions can be quoted, where plants accidentally or intentionally introduced by man into new areas have not only maintained a foothold, but have spread remarkably. Note the case of the Sweet-brier (*Rosa eglanteria*) in New Zealand, of the Mexican *Bryophyllum calycinum* in many Tropical countries, of the American Monkey-flower (*Mimulus Langsdorfii*) in our own islands; but these are admittedly exceptional. It is nearer the truth to say that the troubles of an immigrant only begin where dispersal ends; and that the chance of seeds carrying out a successful migration is much greater than the chances of their giving rise to a new colony when that migration is successfully accomplished. Every head of the Reed-mace liberates about a quarter of a million seeds of marvellous lightness; yet the Reed-mace does not increase in the country, nor is it a particularly abundant plant even in its chosen habitats. The Fox-gloves (*Digitalis purpurea*) in a wood shed, each plant, say a hundred thousand seeds; yet on an average only one of these attains maturity, otherwise the species would become more abundant in the area. This enormous destruction of seed is largely due to competition. The reception which a plant receives in its new home is the thing that matters, and that may usually be summed up in the phrase "House full."

Nevertheless, the present flora of Great Britain is in the long run the result of migration from surrounding areas; so that ease of dispersal has undoubtedly

played its part in the building up of our vegetation.

Conditions under which rapid dispersal has obviously an advantage occur when by some exceptional circumstances the natural vegetation is destroyed within an area, as by a flood or landslide. Such conditions are produced artificially each season over much of our own country by the operations of agriculture. Their results will be considered in a subsequent chapter.

CHAPTER IV

SOME INTER-RELATIONS OF PLANTS AND ANIMALS

THE most important and fundamental difference between the animal and plant worlds is this: plants possess the power of manufacturing their food out of the inorganic materials of which it is composed, while animals cannot do this. Give an ordinary plant access to water with a pinch of mineral salts in it, to the air, and to sunlight, and by the agency of chlorophyll—the green colouring-matter of the leaves—the miracle will be accomplished, and dead materials transformed into living substance. Animals, on the other hand, are dependent for their food-supply on organic material—that is, on either plant or animal substances; and since they cannot live by taking in each other's washing—in other words, by eating each other—it follows that the animal world is dependent on the plant world for its continued existence. A porpoise may live on herrings, herrings on small fry, fry in turn on minuter organisms, and so on down the scale; but their ultimate source of food is the tiny Algæ which swarm in the water—the *Plankton* in Hensen's original sense—which, alone in this chain, can build up their bodies out of the sea and air. That these minute plants can sustain the enormous drain upon them due to their use as a food-supply by myriads of larger organisms is due to their vast numbers and rapid increase. Sea-water

favourable for plankton life may contain several millions of individuals in every litre (about $1\frac{3}{4}$ pints); while as a fair estimate for the seas which surround our own islands "at least one" organism for every drop has been suggested.*

In the great abysses of the ocean, where vegetable life is absent, the strange creatures which live there in utter darkness prey upon others, and they again on others which belong to lesser depths, the ultimate source of life being again the minute surface organisms which, possessing chlorophyll, can make organic out of inorganic substances by the energy obtained from sunlight. Thus only is life made possible in

> the green hells of the sea
> Where fallen skies and evil hues and eyeless creatures be.

On the land, the dependence of animals on plants is in large measure direct, as the supply of vegetable food is abundant and widespread. The largest land animals are all vegetable feeders; so are the majority of our own native mammals, and in a great measure our birds; while most of the creatures upon which the flesh-eating animals prey are themselves vegetable feeders. The distribution of land animals over the globe is thus dependent in large measure on the distribution of plants. On account of the profusion and variety of plant life, and the fact that most vegetable feeders can thrive on various sorts of plants, few animals are restricted in their range by the presence or absence of any particular species or genus, but complete dependence of this sort is by no means un-

* See A. H. Church: "The Plankton-phase and the Plankton-rate," *Journal of Botany*, June, 1919, supplement.

known. The larvæ of some Butterflies, for instance, eat the leaves of one plant only; the Peacock (*Vanessa io*) and the Small Tortoiseshell (*V. urticæ*) are cases in point. The caterpillars of both these species feed exclusively on the Common Nettle (*Urtica dioica*). Should the efforts of farmers and gardeners succeed in exterminating this unwelcome plant, these two butterflies would disappear from the Earth. Sometimes absolute mutual dependence is found on both the animal and vegetable sides. The American *Yucca filamentosa*, often grown in our gardens, depends solely on the little moth *Pronuba yuccasella* for its pollination, just as the insect is absolutely dependent on the plant (see p. 80), and other species of Yucca have each its particular dependent moth, which feeds on no other plant, and whose flowers are pollinated by no other.

Apart from such special cases, the general dependence of animals upon plants is obvious, and is by no means confined to food-supply. Animals of all grades, from human beings to Caddis Worms, construct houses of vegetable materials; trees are the chosen home of large sections of our fauna, and the herbs of the field are the world for millions of tiny beings.

> There's never a leaf or a blade too mean
> To be some happy creature's palace.

Turning to the other side of the picture, no such general dependence of the plant world upon the animal world is found, but the inter-relations of the two are many and varied, and in the absence of animals of one kind or another whole groups of plants would become extinct. The cases where plants derive their

food-supply wholly from animals are indeed rare, save near the bottom of the vegetable scale, and most of such parasites are minute; one of the most noticeable in our own country is the fungus *Cordyceps militaris*, which may be found growing on the dead bodies of larvæ or pupæ which it has killed—a little scarlet, club-shaped plant, about an inch in height. But some of the most highly organized plants obtain *portions* of their food-supply from animal sources. Mention has already been made of the Sundews (*Drosera*), Butterworts (*Pinguicula*), and Bladderworts (*Utricularia*), which capture live insects, etc., by means of sensitive organs (as in the first two cases) or ingenious traps (as in the last), and subsequently digest them, and they will be dealt with later on (p. 186). Then there is the Venus' Fly-trap (*Dionæa*) and the well-known Pitcher Plants (*Nepenthes*), which actively, as in the former case, or passively, as in the latter, catch insects and digest them, by means of leaves modified in very extraordinary ways. In all these instances the advantage lies entirely on the side of the plant, just as in the case of most of the plant-eating animals the advantage is wholly with the animal. But in a large number of instances—many of them of a most interesting nature—the inter-relations are such as to benefit both the actors, each obtaining from the other what is useful to it. One of the most conspicuous and wide-spread relationships of this kind is that prevailing between flowers and insects, the insect receiving food in the form of nectar, and at the same time carrying pollen from flower to flower, without which transfer no fertile seed would be formed. To this interchange of favours we shall return later (p. 81); meanwhile, it

will be well to consider a few of the cases in which the relationship between plant and animal is continuous and more intimate, the two living in very close relations to each other: to such cases the term *symbiosis* or "living together" is applied by naturalists. The relations existing between certain trees and some species of ant are of high interest, and illustrate well this phase of life. The Candelabra Tree (*Cecropia peltata*) of the South American forests is liable to attack by leaf-cutting ants (*Œcodoma*), which climb trees and bite off thousands of leaves; these they cut up on the ground and carry to their nests, where they form a basis for the growth of certain small fungi which are a favourite food of the ants (compare the cultivation of mushrooms as practised by gardeners). The Candelabra Tree protects itself from these ravages by forming an alliance with another kind of ant (*Azteca*). Along the hollow stems are little pits through which the ants easily bore, and reach the convenient houses within, where they live and bring up their young. At the base of the leaf-stalks, where the greatest danger lies from the leaf-cutting ants, little tufts of hairs are situated, among which are small white masses of nutritious material much liked by the ants, and collected by them and stored within their houses. So that these desirable trees are swarming with Aztec ants, fierce little creatures—"it is one of the most bellicose ants that I know, and its sting is most irritating," writes Kerner—which congregate especially at the leaf-stalks, the point of attack of the leaf-cutters. The advantages of these arrangements to both the trees and the Aztec ants are obvious.

A very remarkable instance of a different kind is supplied by the relations existing between the American species of *Yucca* and the small white-winged moths of the genus *Pronuba.* The following succinct account is given by Professor G. H. Carpenter: * "The female of these moths has not only the palps of the first maxillæ developed, but the region of the maxillæ (palpiger) whence they spring produced into a pair of long, flexible, hairy processes. By means of these she collects from the anthers pollen, which she deliberately carries to the stigma to ensure fertilization. With her piercing ovipositor—a most abnormal development among moths—she bores through the tissue of the pistil, and by means of the flexible egg-tube, protrusible beyond the ovipositor, lays her eggs close to the ovules of the *Yucca.* The caterpillar when hatched feeds on the growing seed of the plant, which would never develop were it not for the action of the *Pronuba* moth. This action is most wonderful, in that the moth herself gets no benefit from it. Her food canal is degenerate, and her jaws, useless for sucking, are devoted altogether to the gathering of the pollen; she does not feed in the perfect state. Doubtless her ancestors did so, and were first attracted to the *Yucca* in search of honey, though the act of pollination is now performed only for the sake of the offspring."

Among certain lower animals and plants symbiotic connection is often most intimate. For instance, in the body-wall of certain Sea Anemones and Holothurians there are small green cells which were long

* G. H. CARPENTER: "Insects: Their Structure and Life," p. 300.

believed to be part of the animal, and which puzzled naturalists because they contained chlorophyll, that remarkable green substance characteristic of plants, which gives to them the power of forming food out of its raw inorganic materials. These cells are now known to be minute seaweeds (Algæ), which spend their lives in the animal tissues to the benefit of both organisms. The plant, by virtue of its chlorophyll, absorbs carbon dioxide, decomposes it, and gives out oxygen, which is eagerly seized on by the animal. The animal in its turn liberates carbon dioxide, which is required by the plant. Similar relations exist between Algæ and some of the lowly Radiolarians and Foraminifera; in these cases, the animals being very minute, the plant partner plays a more conspicuous rôle. It is noteworthy that these Algæ are quite capable of living and multiplying separately, free from the body of the animals, and the animals also are capable of pursuing an independent existence.

Let us turn now to the relations existing between flowers and insects, which form one of the most picturesque and romantic features of field life, and of which the materials for study and observation are ever at our own doors. What is a flower? A flower is a group of modified leaves set apart for the business of sexual reproduction. The essential parts or *sporophylls* are of two kinds, which may be borne on the same flower or on separate flowers on one plant, or on separate plants. These are the *stamens*, bearing *pollen grains* (or *microspores*), from which *male cells* arise; and *carpels*, which contain *ovules*, each enclosing an *embryo sac* or *megaspore*, in which is an *ovum* or *female cell*.

Each stamen consists usually of a slender stalk, the *filament*, bearing an oblong head, the *anther*, which contains four chambers, or pollen sacs, filled with pollen grains; these, when mature, escape into the air by the rupturing of the walls of the chambers.

Each carpel contains in its lower part an ovary, while its upper part presents to the air a surface charged with nutrient substance, the *stigma*, which is often raised on a slender stalk, the *style*.

To secure the production of seed, the first necessary step is *pollination*, or the transfer of pollen from the stamen to the stigma. When this is effected —the means will be considered immediately—and a pollen grain alights on the surface of the stigma, which is usually sticky or hairy to aid its retention there, the pollen grain commences growth, and sends out a slender tube (the *pollen tube*), which pursues its way through the substance of the stigma, down the style, into the ovary, and from its tip a male cell passes out and fuses with the ovum. In most flowers the pollen tube is not called on to make any great effort of growth, the distance between stigma and ovary being very small; but occasionally, as in Crocus and Lily, this may amount to half a foot. The result of this act of fertilization is that the ovum and ovule grow, the former forming eventually the *embryo*, or young plant, the latter the *seed* in which the embryo is enclosed. In order that fertile seed may be produced it is often necessary, and usually desirable, that the pollen which reaches the stigma should not belong to the same flower, but to a different flower of the same species; *cross-pollination* being the rule among seed plants, *self-pollination* the exception. To secure

the former, and to avoid the latter, many highly interesting devices are found, materially affecting the structure and development of flowers.

The *essential* parts of a flower, then, consist of stamens and carpels. Flowers consisting of no other parts but either or both of these are not common, but we may compare, for example, the rarely produced flowers of the Duckweeds (*Lemna*), in which a tiny group of two stamens and a carpel represents one flower, or, according to some views, a group of three flowers. More commonly the flower is much more composite, consisting mostly of four sets of organs, arranged in whorls or rings, or more rarely in close spirals. In the centre is a group of carpels; outside them—in other words, slightly lower on the stem—a ring, or two rings, of stamens, few or many; then a ring of *petals*, forming the *corolla*, usually coloured, leaf-like, and conspicuous; and outside of them a ring of *sepals*, forming the *calyx*, generally green and leaf-like. The main function of the calyx is protective; it encloses the essential organs and guards them till they are mature, when the flower opens and stamen and stigma play their parts. The calyx is usually tough, and often covered with hairs, or with a sticky substance, to keep the flower safe and ward off the attacks of insects or other small devourers. If we turn to the corolla we find a singular variety of size, form, and colour. To account for this, it is necessary to consider the means by which pollen is distributed. There are two chief ways in which pollen is conveyed from flower to flower—by means of the wind, and by means of flying insects. If we examine wind-pollinated flowers, such as Hazel (*Corylus*), Scotch Fir

(*Pinus*), or Reed-mace (*Typha*), we note the small size of the flowers and the great abundance of pollen. Compare these with insect-fertilized flowers, such as Buttercup (*Ranunculus*), Flax (*Linum*), Snapdragon (*Antirrhinum*), or one of the Orchids. In these the flowers are much larger owing to the increased size of the petals, which are of brilliant colour and of various shape. Pollen is mostly much reduced in quantity, since insects flying direct from flower to flower afford a far more economical mode of distribution than is offered by the wind. The pollen grains, moreover, are sticky and covered with tiny spines or knobs, to render them more liable to adhere to the body or head of an insect; the pollen grains of wind-fertilized flowers being, on the other hand, smooth, dry, and dust-like. Again, these insect-pollinated flowers usually possess little glands which secrete nectar, the sugary syrup which by digestion in a bee's body becomes honey. Here, then, is the inter-relation established: the insect helps the plant by carrying its pollen from flower to flower, and in its turn is helped by the provision of delicious food. And what about the showy petals, and the fragrance that so often marks these entomophilous flowers? They are advertisements, designed to catch the attention of the necessary insects as they fly about. Not only does the corolla by its bright colour attract insects, but markings of various shapes and tints upon the petals are generally held to be honey-guides—sign-posts directing the insects to the nectar and to the pollen. These are especially conspicuous in many of the irregular flowers to which reference will be made shortly, in which the insects are encouraged to approach the flowers in a particular way. An example

of such markings, as seen in the genus Erodium, is shown in Fig. 14. It is interesting to note the various ways in which flowers render themselves conspicuous in order to attract insects. In the majority of Seed Plants, such as the Buttercup, Pea, Rose, Foxglove, it is the corolla, formed either of separate petals, as in the first three, or of petals fused together, as in the last, which by its bright colour or colours renders the flower noticeable. In other species the calyx takes on

FIG. 14.—FLOWER OF ERODIUM PETRÆUM. $\frac{2}{1}$.

the function of advertisement, the corolla being in comparison insignificant—we may study examples of this in the Anemones, Hellebores, and Marsh Marigold (*Caltha palustris*). It is worth examining this last, to see how its coloured *sepals* resemble and fulfil the same function as the *petals* of its cousins the Buttercups. Or, again, sepals and petals may combine in showiness, both sets being brightly coloured in one or more tints—compare the Columbine (*Aquilegia*), Larkspur (*Delphinium*), Milkwort (*Polygala*), and the marvellous flowers of Orchids. In the great group of the Monocotyledons, indeed, to which

the Orchids belong, sepals and petals usually combine in form and colour to form one corolla-like envelope (then called a *perianth*). In many other plant groups —for instance, the *Dipsacaceæ* (such as the Scabious), *Umbelliferæ*, and *Compositæ*—conspicuousness is obtained by a grouping together of a large number of small flowers. In the Cow Parsnep (*Heracleum Sphondylium*) the outer petal of the marginal flowers

FIG. 15.—UMBEL OF ASTRANTIA CARNIOLICA, SHOWING PETAL-LIKE RING OF COLOURED LEAVES (BRACTS). $\frac{1}{1}$.

of the large umbel is much enlarged, which enhances this effect. In *Astrantia*, an interesting genus of *Umbelliferæ*, the bracts take on the appearance of a ring of large petals, and surround the group of small flowers (Fig. 15). The same thing may be noticed in the outer blossoms of the close flower-head of the Field Scabious (*Knautia arvensis*). In many *Compositæ* the process is carried still farther; in the Com-

mon Daisy (*Bellis perennis*) the outer flowers have each a long strap-shaped expansion of the corolla, which is of a different colour (white) from that of the corollas of the inner flowers, which are yellow. In the Dandelion (*Taraxacum officinale*) all the flowers have a yellow strap-shaped corolla. In the Guelder Rose (*Viburnum Opulus*) the outer flowers are entirely devoted to advertisement, consisting each of a big white corolla, while only the small inner flowers possess stamens and pistil and are capable of producing the brilliant scarlet berries. In a cultivated form of this, commonly called the Snowball Tree, the advertisement flowers only are present, forming a globe of white blossom, and no fruit is produced in consequence. The Dwarf Cornel (*Cornus suecica*), a little Dogwood growing on many Scottish moors, bears what looks like a white flower with a purple centre. On examination it is seen that the four white petal-like structures are really foliage-leaves, which have taken on the duty of advertising the group of small purple blossoms which they enclose (Fig. 16). A similar and very gorgeous effect is produced in several Spurges often seen in greenhouses, such as *Euphorbia fulgens*, *E. splendens*, and *E. punicea;* in these the upper foliage-leaves are large and coloured brilliant scarlet, the flowers which accompany them being quite small. These aggregations of flowers with their flaunting flags are in general an invitation to all comers; the nectar in the blossoms lies open to every hungry insect, and pollination is effected in a rather promiscuous and messy way; not only flying insects—bees, butterflies, beetles, and flies of many sorts—but also ants and other creatures which creep up the stems

from the ground, assemble for the feast, and incidentally transfer from flower to flower pollen which may adhere to their bodies.

In a large number of flowers such general feasting is discountenanced, insect traffic is regulated, the

FIG. 16.—DWARF CORNEL (CORNUS SUECICA), $\frac{2}{3}$, AND SINGLE FLOWER ENLARGED.

visits of insects of little or no service to the plants is discouraged, and special arrangements are made to attract and minister to the needs of those insects whose visits are of most benefit. Except where

flowers are borne in clusters, creeping creatures like ants are of no service; for in the course of the journey "by land" from one flower to another, there is a strong probability of any pollen which the insect may be carrying being rubbed off before the next blossom is reached; small flying insects are likewise frequently useless. In many plants the visits of such pedestrians and small fry is very distinctly discouraged. Of different devices which serve this end, the most conspicuous and effective include barriers to the passage of stem-climbers, and devices in the flower preventive of the visits of unwelcome guests. We may take a few instances from among British plants, which the reader may with a little diligence find and study for himself. Several members of the Pink family (*Caryophyllaceæ*) produce a sticky secretion which is a very effectual bar to the passage of small walking animals. In the English Catchfly (*Silene anglica*), Night-flowering Catchfly (*S. noctiflora*) and the Nottingham Catchfly (*S. nutans*), hairs are present all over the leaves and stems, from the tips of which a gummy substance exudes, which is a fatal trap for small insects. Kerner, in his interesting book, "Flowers and their Unbidden Guests," states that on the sticky stems of the last, in the Tyrol, he identified the remains of sixty different kinds of insects—ants, ichneumons, beetles, bugs, flies, and so on. The Red German Campion (*Lychnis Viscaria*) has an extremely sticky ring below each joint of the stem and inflorescence, which is most fatal to any creature which attempts to climb to the flowers. Other instances, such as the Petunia or Moss Rose, will occur to the reader. Another familiar kind of barrier is the presence on the calyx or involucre

of a palisade of stiff hairs or prickles, such as may be studied in the Thistles; in some plants a downward-pointing ring of stiff hairs at each joint serves the same purpose. In the Japanese Wineberry (*Rubus phœnicolasius*), often grown in gardens, the calyx, like the stem, is densely clothed with bright red slender spines (Fig. 17). It opens to allow the inconspicuous

FIG. 17.—JAPANESE WINEBERRY (RUBUS PHŒNICOLASIUS). Leaf and panicle, $\frac{2}{3}$; flower after pollination; ripe fruit, both slightly enlarged.

petals to expand, and then closes again and resumes its protective rôle till the scarlet fruit approaches maturity.

But it is in the flower itself that we find the most ingenious arrangements to encourage useful and discourage useless visitors, to assist the former to pollinate the flower, and while offering nectar to the wel-

come guest to deny it to the unwelcome. The first stage in this specialization is that the flower, instead of having its axis vertical, and facing the sky, is turned on its side by the curving of its stalk, and looks out horizontally. The effect of this is to cause a flying insect on approaching the flower to alight in a particular position—namely, on the lowest petal. Following on the adoption of this attitude the next stage in development is seen in the parts of the flower beginning to alter their shape and position relative to each other and often also their colour. Thus, beginning with a quite regular flower, we can arrange a series showing more and more asymmetry. The tendency is generally for the lowest petal to become enlarged and often conspicuously marked, providing a broad, convenient platform on which insects may alight, while the remainder form walls and roof, protecting the important parts within and by their shape, which is often narrowed and tubular behind, barring access to all but chosen visitors. To find a full series illustrating these transformations we do not need to go to plants widely separated in their affinities. In the Buttercup order (*Ranunculaceæ*) alone every gradation may be found. The flowers of the Buttercups themselves are upright and quite regular. In the Larkspur (*Delphinium*) the flower is turned on its side, and a puzzling combination of coloured sepals and petals—five bright blue unequal sepals and a single large purplish petal of peculiar shape with a long hollow spur behind—produces a quite irregular blossom. The process is carried farther again in the Monkshood (*Aconitum*), in whose well-known blue flower the sepals and petals combine to produce a

strikingly irregular blossom, with the upper sepal arching over into a great hood protecting the rest of the flower. In such irregular flowers the essential parts—the pollen-producing and pollen-receiving portions, or stamens and stigma—also alter their position and form, and are so placed that an insect, visiting the flower to obtain nectar (which is generally stored at the back, well out of the way), must of necessity receive pollen on its body, and probably deposit pollen on the stigma. To describe the variety and ingenuity of these devices as found in different flowers might well occupy several chapters, and only one or two examples can be quoted here; familiar wild flowers are chosen, and the reader should examine them for himself to understand their structure. In the well-known Pea type, one great petal arches over the flower; two narrow ones stand one on either side; the remaining two stand on edge below, with their margins in contact, enclosing the stamens and pistil. An insect visiting the flower alights naturally on the *keel* or pair of lower petals. Pressed down by its weight, these open, often with a sudden movement like bursting, and dust the insect with pollen. Compare also the flowers of the Snapdragons (*Antirrhinum*) and Toadflaxes (*Linaria*), in which the upper and lower lips of the corolla meet like a closed mouth, which can be forced open only by a strong insect like a bee, and is safe from predatory visits of smaller fry (Fig. 18). In the Sages (*Salvia*) the corolla is tubular at the base; there is a large lobed lip on which visiting insects alight, and a hooded roof above arching over the stamens and pistil, which are placed close against it, overhanging the entrance to the corolla-tube, at the base of which the

nectar is stored. The stamens, only two of which are developed, have each a hinge near the top, the part above the hinge being like a curved rod supported near its middle. These two curved rods stand normally in a vertical position, so that their lower ends partly block the entrance to the tube; the pollen is borne at their upper ends. Should a bee insert its head down the tube in search of nectar, it pushes the lower ends of the hinged rods upwards, with the

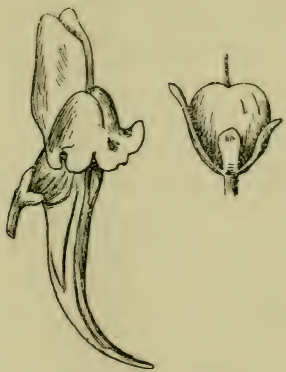


Fig. 18.—Flower and Fruit of Linaria purpurea. $\frac{2}{1}$.

result that their upper ends swing downward against the bee's back, dusting it with pollen just at that part of its body which, if the bee should visit a rather older flower, would come in contact with the stigma, the slender stalk of which (the *style*) increases in length during the period of flowering, and is in consequence the more liable to be encountered.

Only one more instance can be referred to, which can be tested by the reader any summer day wherever

any of our native Orchids grow. In these, the most highly specialized of all plant groups as regards pollination by insects, the general arrangement of the flower is often somewhat similar in a general sense to the last case; but here the sepals and petals which between them form the platform, tube, sides, and roof of the flower, are all separate and often differently and elaborately coloured. The essential organs are greatly modified and hardly recognizable at first. There is only one stamen, producing two clusters of pollen, which are embedded in the roof of the flower. Each possesses a slender stalk which terminates in a little sticky disc which projects from the general surface. The pollen grains are held together in a mass by fine threads, and the whole with its stalk—the *pollinium*—resembles a lemonade bottle in shape. The stigma is also embedded, forming a sticky surface in the roof of the flower behind the stamen. When an insect inserts its head into the flower, its forehead comes in contact with the sticky ends of the pollinia, which adhere, so that on leaving the flower the insect flies away with the pollen sticking to its forehead like two little horns. And now a remarkable thing happens. The stalks of the pollinia, drying rapidly in the air, contract unequally, and become curved, so that the pollinia bend forward into a horizontal position. When the insect visits another flower and thrusts in its head, the pollen consequently comes in contact with the sticky stigmatic surface farther down the tube, and cross-pollination is effected.

In the cases of many of these highly specialized flowers, one is no less struck with the perfection of the arrangements made for preventing self-pollina-

tion, than those adapted to securing cross-pollination. But in a few, on the contrary, self-pollination is specially arranged for.

It must be pointed out that the insects which pollinate these specialized flowers have in many cases acquired modifications in their structure corresponding to the modifications in the flowers which they frequent. In the more specialized forms, indeed, plant and animal have become entirely dependent on each other; the plants would become extinct in the absence of the special insects through whose agency they are able by pollination to produce fertile seed; and the insects would likewise die out if the flowers to whose nectar and pollen they look for food were not available.

As regards the kinds of insects which visit flowers for food, these are very numerous and belong to almost every section of that large class. In many, such as Neuroptera, Orthoptera, Hemiptera, Coleoptera, there is very little special adaptation for their flower-feeding habits, and these insects visit flowers, such as the *Umbelliferæ*, in which the nectar and pollen are freely exposed, and lie open to all. Many of the Diptera, or Flies, are in the same case; but in some families, such as the *Bombyliidæ*, high specialization for securing food from flowers is found: the creatures are provided with elongated probosces for sucking nectar even when it is deeply hidden, and no other food is used by the insects in their adult stage. But it is among the long-tongued Bees and the Lepidoptera (Butterflies and Moths) that the highest degree of adaptation in this direction is found; and the modifications are associated with those flowers

which have become most highly specialized for insect pollination, and most completely dependent on it. In the Bees the legs have become much modified for the gathering of pollen, and the mouth is a long flexible sucking-tube which when not in use is carried rolled up in a spiral. The pollen, on which food alone the young bees are fed, is gathered and stored among rows of hairs on the legs, and in the more highly specialized forms it is wetted with honey so as to form a compact mass, easily carried and easily removed when the nest is reached. The balls of pollen thus formed are sometimes nearly the size of the body of the bee, and may contain one to two hundred thousand grains of pollen. The formation of the mouth is beautiful and complicated, adapted to the rapid sucking up of nectar even if deeply placed in the flower. The nectar is stored in the body of the bee, and subsequently transferred to the waxen honey-cells in the hive. In the Butterflies and Moths the mouth parts are also modified for sucking, and as these insects do not build nests or take care of their offspring as Bees do the mouth is formed solely for the purpose of securing the nectar which is their only food. The proboscis varies greatly in length in different groups, according to the kind of flower which they visit. In the Owl Moths (*Noctuidæ*) it is sometimes only eight millimetres ($\frac{1}{3}$ inch) long; in many of the Butterflies it is about half an inch. In the Hawk-moths it attains a remarkable development, necessitated no doubt by the habit of these insects of not alighting on or entering a flower, but hovering in front of it as a Humming Bird does, and sucking up the nectar while thus poised. The proboscis of

the Convolvulus Hawk-moth measures 65 to 80 millimetres ($2\frac{1}{2}$ to $3\frac{1}{4}$ inches), and some of the Tropical allies of this moth have probosces twice or even three times that length. These species feed on the nectar of flowers with tubular corollæ of corresponding dimensions. Most of the Hawk-moths feed only at dusk, and as the time is short they take advantage of their powers of rapid flight to visit (and incidentally to pollinate) a very large number of flowers in a short period. Moreover, in common with most of the more specialized flower-feeding insects, they do not visit the flowers of different species indiscriminately, but dash to blossom after blossom of whatever single species they have selected. Hermann Müller records watching Humming-bird Hawk-moths (*Macroglossa stellatarum*) at work at the summit of the Albula Pass; one visited 106 flowers of *Viola calcarata* in under 4 minutes; another 194 blossoms of the same plant in $6\frac{3}{4}$ minutes.

The day-flying Butterflies display none of this restless energy. The sunshine is pleasant and the day long. They wander aimlessly in their beauty from flower to flower, sun themselves on the warm ground, or "whirl through the air with the first good comrade that by chance appears." They are the flowers of the air, and our country rambles are made more joyous by their careless companionship.

CHAPTER V

PLANT STRUCTURES

In the course of the preceding chapters a number of the more striking modifications displayed by the different organs of plants have been described briefly. Reference has been made to the increased length or thickness of the roots in plants of dry places, and the weakness or absence of root-system of many water plants. Corresponding variation in stems has been noted. The remarkable leaves of desert and water plants and of some carnivorous species have been mentioned. The profound alteration in flowers which have adapted themselves to pollination by insects has been sketched; as also the great variety in the shapes of fruits and seeds, correlated to the methods by which they are dispersed. It may be well to consider the question of plant structures on a broader and more systematic basis, and, as before, to connect them where possible with the external factors which have caused their modification and to which they are the plant's response. These factors are physical, or chemical, or biological, and affect the plant mainly through the agency of the soil, the atmosphere, or living organisms.

"The living plant is a synthetic machine." Under proper working conditions of heat, moisture, and light it builds up its body by absorption of inorganic

material, liquid and gaseous, through its roots and leaves. For the present purpose we may take our typical plant as consisting of subterranean roots and aerial leaves on the one hand, and aerial flowers on the other—the roots and leaves concerned especially with carrying on the life of the individual, the flowers with perpetuating the race. In addition, an aerial stem is usually present, on which the leaves and flowers are displayed, and through which the food materials pass dissolved in water. Of these parts, the lower ones (the roots, and sometimes the stems) are immersed in the soil, while the upper ones (the leaves and the flowers—which are groups of modified leaves—and usually the stems) are immersed in the atmosphere. All the parts have acquired their form and fulfil their functions under control of the particular medium which surrounds them: it becomes necessary to preface any discussion of their characters and uses by a brief survey of the characters of these envelopes.

While the atmosphere is familiar to us as the medium in which we ourselves live and move and have our being, and while its chemical and physical properties are known in outline to every schoolchild, it is different with the soil; not only because, unlike the atmosphere, soil varies much in composition and character, but also because the soil is in fact a very complex product, offering many difficult problems to the investigator; it is only of late years that the scientific study of the soil has been placed on a sound basis; our knowledge of it is still far from complete.

Whence does soil arise? How is it that the surface of the land is usually covered with a layer of fertile

material? The answer is to be found, in the first place, in the decay of rocks under the influence of natural agents. Heat and frost, rain and drought, by slow degrees break up the surface of the hard material of which the solid crust of the Earth is built up. The débris thus formed is washed into streams by rain, or scattered by wind. A stream flowing into the sea, and charged with the débris of the land, deposits the coarser material near its mouth, while the finer particles are carried farther. In dry regions wind plays a similar part. And so, while the materials which composed the surface layer of the cooling primitive Earth may have been tolerably uniform in composition, the débris derived from them has ever tended to get sorted out, as, for instance, into sand and mud at river mouths, or sand and dust in dry regions. In the course of ages the sorted materials, buried beneath subsequent deposits, have been formed through heat and pressure into rocks, which, when at length again brought to the surface by earth movement and exposed to the agents of disintegration, have been resolved once more into sands, clays, and so on. In the long history of the Earth this sorting process has been repeated till now large tracts of rocks and of soils are composed mainly of sand or mainly of clay. The prevalence of these two kinds of material arises from the abundance in the primitive crust of the substances of which they are composed. Silica (oxide of silicon), the material of which ordinary sand, as well as quartz, flint, etc., is composed, is of extreme hardness and insolubility, and its small crystals and fragments, disintegrated from the rocks, remain almost indestructible as grains of sand. Clays, on the

other hand, are derived from silicates (compounds of silicon and oxygen with various metals such as aluminium, calcium, magnesium, potassium, sodium, or iron). These substances mostly disintegrate more completely into very small particles, which when wet cohere into a sticky mass and form clays. Along with the humus matter they include all the *colloids* of the soil. These latter bodies consist of the extremely minute—indeed, ultra-microscopic—particles, having in consequence of their small size a great total surface in proportion to their mass. In virtue of this, they function as the chief absorbents of the soil, holding water in enormous quantities, and abstracting and retaining till used by the plants the bases of the various substances applied as manures. Another constituent of the primitive crust was lime (oxide of calcium). Unlike the preceding substances, lime is readily soluble in acid water, and so is washed out of the rocks and carried in solution to the sea. Marine animals of many kinds—such as Molluscs, Corals, Foraminifera—extract the lime from the sea water and use it in large quantities to build up their shells or skeletons. This material slowly accumulates at the bottom of the ocean as generation after generation of animals passes away, becomes at length consolidated by heat and pressure, and through earth movements may eventually appear above the sea to form land, in the form of limestone or chalk. Exposed to the weather, it is once more slowly disintegrated; the lime passes off again in solution, the impurities being left behind; a limy soil results.

On a great plain, devoid of hills or rivers, composed of different rocks, and subjected to the agents of

disintegration, we can conceive that over each kind of rock a soil would be formed corresponding closely to the materials of which that rock is composed. In sections formed by quarrying, by the cutting action of rapid streams, and so on, we may often see this. Below is the solid rock. Its upper layers tend to be loose and rotten owing to the action of percolating water, etc. They merge into a layer of stony débris, where the harder portions still retain their rock character, while the softer are disintegrating into clay or sand. Above this the rock is wholly disintegrated into a soil, the upper layers of which, mixed with plant débris, and consequently of darker colour, are full of the roots of living plants descending from the sward which covers the surface of the ground. In practice, however, such close conformity of soil to underlying rock is not always found.

Various distributing agents are ever at work—wind, water in an especial degree, and on sloping ground the action of gravity. In northern countries, besides, the ice of the Glacial Period has in its passage caught up all the loose surface material, added immensely to its volume by grinding down the rocks, and flung the products broadcast over the country, so that old sea bottoms may be strewn over coastal lands, sands and gravels over clayey rocks, and limy soils over areas where no limestone exists. The soil over much of the British Isles is formed from the surface-layer of these glacial deposits, which—tough, intractable, sterile—underlie the soil often to a great depth, where they rest on rock. In southern England the covering of glacial deposits is absent, since the ice-cap did not extend beyond the Thames valley; beds

much older than the Ice Age, often of a gravelly or clayey nature, occupy the ground, and from these the present soils are derived.

There is another constituent of soils of primary importance for vegetable life, which results from the decay of the generations of plants which have gone before. When plants die, their bodies are decomposed by the agency of bacteria. Some of the constituents pass off as gas or water, but there remains an amount of solid matter (humus) which mixes with the soil and is of the utmost importance for plant growth. Nitrogen, which forms the greater part of the atmosphere, cannot in the gaseous state be absorbed by plants, although they spend their lives surrounded by it. It is a necessary substance in the plant's economy, and through the action of soil bacteria, which change the nitrogenous matter in humus into soluble nitrates, plants are able to utilize this store.

The ordinary soils of our fields may be defined as a mixture of sand, clay, and humus. A soil which is too rich, or too poor, in any one of the three will support plant life with difficulty.

The roots of plants require also a due amount of both water and air if they are to fulfil their functions adequately. An examination of the minute structure of the soil shows that it consists of angular particles of very various size—the larger ones classed as sand and consisting largely of silica; the smaller, which decrease in size beyond the limits of microscopic vision, mainly of clay (silicates) and humus. A film of water clings round each particle, and between the particles the chinks are filled with air. For healthy plant growth a nice balance between these constitu-

ents is required. Should sand be in excess, the soil is impoverished, since silica contains no nutriment, and it is rendered too dry, as on account of the relatively small surface of the sand grains in proportion to their mass it retains but little water. Should there be too little sand, percolation of air and water is hampered; the soil tends to become water-logged and badly aerated, and turns sour. Should humus be absent, the nitrogen-producing bacteria cease their activities and the soil is sterile, as may be tested by digging up some *subsoil*, or soil from the deeper levels to which roots or other organic matter have never penetrated. An excess of humus, on the other hand, results in the accumulation of acid products inimical to bacterial growth: in consequence decay is arrested, and a mass of plant débris forms, highly charged (for humus is very spongy) with acid water and badly aerated, which is unsuitable for vegetable growth: we may study an extreme case of such conditions in our peat bogs. Should water be in excess in soils, air is forced out in proportion, and the roots cannot breathe. Too much air means a corresponding diminution of water, and the plants suffer from drought.

"The soil is not merely a reservoir for the mineral nutrients of plants, but is the seat of complex physical, chemical, and biological actions which directly and indirectly influence soil fertility. These actions are intimately associated with the organic matter of the soil and its bacterial inhabitants. Mineralogy and inorganic chemistry, though helpful, are no longer capable of solving soil problems. Biochemistry and bacteriology, with their modern conceptions of colloids, absorption phenomena, enzymes, oxidizing,

reducing, and catalytic actions, etc., are now rapidly extending our knowledge of the soil as a medium for plant growth."*

Such, then, is the nature of the soil in which plants grow, and from which, by means of innumerable elongated cells (the root-hairs) proceeding from near the tips of the roots, food materials dissolved in water are absorbed; these food materials being produced partly by solution of mineral constituents contained in the soil, partly by the action of bacteria in breaking up organic matter. Soil suitable for plant growth may be looked on as consisting of a mineral framework, carrying in its meshes water (about three-tenths of its volume) and air (about one-tenth of its volume); mixed with the mineral particles is humus of varying amount; and supported largely by the humus is a vast population of organisms, both animal and vegetable, from earthworms to bacteria, whose activities are often essential, generally beneficial, and occasionally prejudicial to plant growth.

The root of a young plant grows downward into the soil under the influence of gravity. Its tip, which has to force its way through the rough material of sand and clay, is beautifully protected by a special *root-cap*, which covers the growing point as with a cushion. The surface of the root-cap is slimy, to aid it in slipping forward, and its cells, which are being worn away constantly, are replaced by the growth of the interior. Should an obstacle such as a pebble be encountered, a root will bend round it and then return to its former direction. Branch roots are given off on

* W. B. Bottomley in "The Exploitation of Plants," edited by F. W. Oliver, 1917, p. 12.

all sides at an angle to the main stem, these also tending in a mysterious way, if their course is disturbed by an obstacle, to resume their former direction of growth; the branches again divide, till at length a complicated root-mass is formed, sometimes of great extent, and capable of extracting water from a large volume of soil. Save for continued growth, the roots show little change in comparison with those exhibited by the aerial parts of plants; safely immersed in the soil, they heed not day or night, storm or calm, but steadily pursue their main function of supplying liquid food material to the green parts overhead.

In many instances roots do not accomplish their work single-handed, but only in co-operation with certain lowly organisms; and these cases are so interesting and of so much economic importance that reference should be made to them. The little swellings or tubercles upon the roots of Leguminous plants, such as Clover, are familiar to most of us. These are caused by the stimulation due to colonies of bacteria (*Bacillus radicicola*), which live in the root-tissues as internal parasites. These bacteria feed on the sap and cell-contents of their host, but they supplement this food-supply by absorbing nitrogen direct from the atmosphere, which the host cannot do, though it can and does use the nitrogenous compounds which the bacteria manufacture. It is a case of symbiosis (see p. 79), each organism supplying food useful to the other; but the significance of the phenomenon is that through this agency nitrogen becomes added to the soil as the plants decay, and increases its fertility; and thus the cultivation of a crop of, say, Lucerne becomes a matter of great economic importance in

farming operations, and the presence of Clover in pasture is a source of increasing wealth.

Again, in the roots of most of our forest trees, both hardwoods and conifers, and of many other plants such as the *Ericaceæ* and *Orchidaceæ*, the root-hairs are replaced by minute fungi known as *mycorhiza*, whose branches take on the function of absorption, while the roots in turn absorb the material which the fungus collects. The fungus obtains from the roots a direct and convenient supply of carbohydrates; the host obtains from the fungus a ready supply of salts and of nitrogenous compounds. In the case of the forest trees and some other plants, the fungus forms a close felt *around* the roots; but in the Heaths, etc., it penetrates the roots, living in the cells and in some instances, as in the Ling (*Calluna vulgaris*), permeating the whole plant, even to the seed-coat, so that seed and fungus are sown together. Since the higher partner of the symbiosis cannot mature without the lower, this is an obvious advantage to the former, as the two develop together from the commencement of growth. Where the fungus is not present in the seed, the seedling has to rely on its presence in the soil. And so, if we wish to raise any of our common terrestrial Orchids from seed, we try to ensure the presence of the fungus by using soil in which the species has been growing already.

The state of mutual dependence existing between seed plants and mycorhizic fungi sometimes ends in the higher organism ceasing to manufacture its food by means of green leaves, and depending wholly on the lower for its sustenance. This is the condition to which some of our Orchids have come, such as the

Bird's-nest (*Neottia Nidus-avis*), which does not produce leaves or chlorophyll, but sends up from its fungus-infested roots merely a scaly brown stem topped with brown blossoms, matching curiously the dead leaves among which it grows (Fig. 31, p. 182).

In contrast to these the case of certain other Orchids may be quoted, which have also lost their leaves, but in a very different manner. In their case the roots, creeping over the bark of trees on which the plants perch as epiphytes, have become green and flattened, like the fronds of some of our native Liverworts; they have assumed the functions of leaves: in them the process of photosynthesis is carried on; and the leaves themselves, thus supplanted, have by degrees disappeared.

Like many other parts of plants, roots are often used for the storage of reserve supplies of food or of water. For this purpose they become much thickened, and this thickening is the most conspicuous change which roots usually undergo. Note the fat roots of many plants which grow in dry or arid places, such as the Sea Holly, Dandelion, and many desert plants and alpines. The thickening is often accompanied by increase in length, as the roots range far in search of water. Another point to notice is that though normally roots differ considerably from their associated stems in general appearance, and also in their minute structure, as in the arrangement of the vascular strands, the two are related. Stem structures are often produced at various points on roots; the suckers sent up by many kinds of trees offer an example. Conversely, roots are readily produced even from the upper portions of many stems—else how could we

grow cuttings? Where roots are succulent—that is, when they have a reserve of food stored in them—cuttings of them will conversely produce stems. A classical instance of such interchangeability of function is the young willow which Lindley bent down and buried the top till it rooted; the original roots were then dug up and raised into the air, when they produced leafy branches, and the tree grew upside down henceforth. Underground stems, also, of which there is a great variety, take on many of the characters of roots, and from an examination of a small piece of one it is often difficult to tell whether we are dealing with a root or a stem. The point at which root joins stem is, in fact, in many instances, so far as function is concerned, fixed only so long as the level of the surface remains fixed: we can often alter it by "earthing up" or by stripping away the soil. In Tropical forests, where the air is moist, hot, and still, roots—or branches which serve only as roots—descend through the air from heights almost equalling those to which stems ascend; while, on the other hand, in hot, poorly aerated swamps, roots send up from the mud into the air stem-like structures (pneumatophores) through which they may breathe, as in the case of the Swamp Cypress (*Taxodium distichum*) of Florida. The primary differences between the two, in fact, do not prevent the one from taking on the general characters of the other, and from functioning as the other, when the environment changes.

The STEMS of plants may be looked on from two points of view—as a framework devoted to the display of the leaves and flowers, and as pipe-lines connected with the nutrition of the plant, conveying raw

materials from the roots to the leaves, and manufactured products from the leaves to all growing parts. It is the former relation which has mainly determined the forms of stems. Even a very slender stem can convey a vast amount of water and food to a plant which is transpiring or growing actively, as we can test roughly by weighing a pot shrub as it begins to come into leaf, and again a week later, or comparing the growth of a pea with the size of its stem at the base. The surprising variation in length, thickness, form, position, and branching of stems is the plant's response to external conditions—such as exposure, the competition of neighbouring plants, and so on—which resolve themselves ultimately into questions of wind-pressure, of temperature, of moisture, and in particular of light. The first duty of most stems is to spread out the leaves so that they may receive a maximum share of sunlight, and the complicated systems of branches with which we are so well acquainted are devoted to this object, the leaves themselves helping materially by the positions which they assume. This familiar and typical kind of stem, upright and column-like, beautifully constructed to bear the weight of leaves and branches, and to resist wind-pressure, alone furnishes a delightful study; but it can be dealt with only very briefly, as also some of the modifications which it undergoes under special circumstances.

To plants which have not taken to a terrestrial existence, and which still inhabit their ancestral home in the water, the stem problem is comparatively simple. A flexible shaft capable of withstanding wave and current action suffices so far as mechanical con-

siderations go; such shafts—as we may observe by watching the Oar-weed (*Laminaria*) on an exposed coast—are effective under very arduous conditions. Those Seed Plants which, evolved on land, have later returned to the water, such as the Pondweeds (*Potamogeton*), have often redeveloped a stem of a similar kind—a flexible shaft possessing a sufficient tensile strength. The specific gravity of such plants does not exceed that of the medium in which they are immersed, and the stem has not to support the weight of leaves and branches. It is, therefore, not surprising to find that the longest, though by no means the bulkiest, of all plants, are found in the sea. Some of the Oar-weeds (*Macrocystis*) of the southern and western oceans attain lengths which have been estimated at 500 to 1,000 feet; but these gigantic Seaweeds are nevertheless slender plants, suspended lightly in the water. But after the colonization of the land by the aquatic flora numerous serious problems had to be encountered and solved before plants in an aerial environment could rise boldly into the air. Extremes of temperature unknown in the water had to be faced. Along with a greatly increased loss of water owing to the presence of air and direct sunlight, the area over which water might be absorbed became largely reduced, the roots alone being now available. The whole weight of branches and leaves and fruit had to be borne by the stem, not only in calm but in storm. No wonder that to meet these conditions, or to avoid such extremes as were avoidable, aerial stems often display great complexity and diversity of structure and form. From the mechanical standpoint the tall stem is especially interesting on account of the beau-

tiful structural adaptations by which it meets the various stresses to which it is subjected. The problem before the plant is to combine a minimum quantity of material with a maximum of strength and rigidity. Strands of toughened fibre, so disposed as to meet the stresses most advantageously, are characteristic of such stems. In the case of many tall annuals, such as the larger *Umbelliferæ*, the principle of the hollow column is largely employed; in proportion to the strength obtained, this is far more economical than a solid column: and economy is particularly necessary

a. *b.*

FIG. 19.—ARRANGEMENT OF STRENGTHENING MATERIAL IN ROOT (*a*) AND IN STEM (*b*) (DIAGRAMMATIC).

in such annual stems, where the time available for construction is short. Transverse partitions at intervals provide stiffening of the whole; and as the efficiency of the toughened longitudinal strands increases with their distance from the centre, the stems are often ribbed, the strands occupying the ribs, with softer substance between. This form of construction may be contrasted with that obtaining in the roots. In the latter the greatest mechanical stress is in the form of a longitudinal pull caused by swaying of the stem under wind-pressure. To meet this the

vascular strands are arranged, not marginally, but in a central bundle, where they can best meet stresses of the kind. In most trees the stems are solid; here economy of material is less urgent, as a long period of years is available for their building up; the great amount of cell-space thus made available for food-storage is a valuable asset to the plant, as is evident from a consideration of the vast amount of fresh tissue produced in a brief period by a deciduous tree when it bursts into leaf. As this material, stored in the stems and roots, has to be sent up to the twigs dissolved in water, and as during the whole period of growth vast amounts of water are transpired, an elaborate and complete pipe-system is intercalated with the reinforced-concrete structure of the tree trunk. Pumped up by the roots, and sucked up by the leaves, water and food pass rapidly from the ground to the topmost twig of the loftiest tree.

To explain the massiveness of a tree trunk we have to remember that, while the cross-section of any structure varies as the square of its linear dimension, the volume varies as the cube of the same. If we double the dimensions of a tree, we increase its weight eight times, but the strength of the trunk is increased only four times. If a tree 100 feet high is supported on a stem 6 feet in diameter, a tree 200 feet high of the same proportions would need a stem not 12 feet, but over 17 feet in diameter, to be supported equally efficiently. This proportion increases rapidly: a similar tree 300 feet high would need a stem 30 feet in diameter; a tree 1,000 feet high would require a stem 180 feet in diameter, or 32,400 square feet in cross-section. We see, then, why a limit of tree growth is

rapidly reached, at about 300 feet, and why the trees which grow to that height have trunks which are one of the wonders of the world, exceeding 30 feet in diameter, or about 100 feet in circumference.

Climbing stems represent efforts on the part of plants to economize material by utilizing the rigidity of neighbouring plants, and by reaching to the light on their shoulders. Here, as in aquatics, the *rope* type of stem is in evidence; it resembles a garden hose, offering great flexibility and conducting capacity, but without rigidity to support its own weight, much less that of the leaves and flowers which it bears. To secure support, the stem itself (or branches of it), the leaves, or the stipules (leafy projections on either side of the junction of leaf and stem), are used. Sometimes support is obtained by twining (compare Convolvulus, Grape-Vine, Vetch), sometimes by adherent discs (Virginia Creeper), or aerial roots (Ivy), often by mere scrambling, often aided by reflexed hooks on leaf and stem (Bramble, Cleavers). The mechanism by which twining is accomplished is of great interest. It is an effect of unequal growth of the different sides of the stem. If the unequal growth were confined to one side, the stem would eventually form a coil, or series of circles. But the region of greatest growth keeps shifting round the stem, with the result that the tip of the shoot describes a circle or ellipse, like the hand of a clock pointing successively in all directions. The stimulus is due, as in the case of the erect growth of ordinary stems (which usually display similar movements in a less degree) to gravity. Sometimes the movement, or *nutation*, is in the same direction as that of the hands of a clock (*e.g.*, in the Hop); more fre-

quently it is in the opposite direction, as of a clock-hand moving backwards. The result of this movement is that if the shoot encounters, say, an upright stem, it will lap round it in a spiral manner, and unless the said stem be quite smooth and unbranched, the twining shoot will be eventually supported by it. How effective the twining habit is as regards economy of building material may be seen from comparing the weight of the stem of a Hop with that of some tall herbaceous plant of the same altitude, and bearing an equal weight of leaves and flowers. The tendril-climbers are still more efficient, for they avoid the increased length of stem which arises from a twining habit. They grow straight up towards the light. Both the top of the growing shoot and the spreading tendrils which arise from it are continuously revolving in search of a support. When a tendril encounters one (such as a twig), the contact produces a stimulus which results in the tendril taking several close turns round the support. Nor does the action stop there, for usually the lower unattached portion of the tendril contracts into a spiral, drawing the stem closer to the support, and woody growth ensues, by which the tendril becomes exceedingly tough, often stronger than the stem itself.

One other point concerning climbers may be noted. Did they exhibit in a marked degree that bending towards the light which is characteristic of most plants, they would often defeat their own object, as they would grow *away from* possible supports. But they grow boldly up into an overhanging canopy, apparently confident of their power to ascend into the light and air which exist above. In the root-climbers,

such as the Ivy, this bending away from the light is very marked; the stem presses closely to the bark or stone on which it creeps, probing every cranny, and the numerous rootlets by which it is attached are developed only on the dark side. But when the plant is old enough to flower, then branches devoid of roots grow out *towards* the light, so that the blossoms may be borne in the open, where they may be seen and visited by the numerous insects which, in their search for nectar, pollinate them.

In contrast to the extreme development in length found in the stems of climbing plants the extreme reduction of stem found in many plants of dry places may be referred to. The Crocus, for instance, has an abbreviated upright stem of which each year's growth is distended for the storage of food: one year's growth dies away as the next enlarges, so that the well-known bulb-like *corm* is produced. Compare the "roots"—really the stem—of Montbretia, in which the annual growths remain, the result being a knobby structure like a string of onions. In bulbs reduction in length is carried still farther, the stem forming a broad cone from the surface of which spring a number of modified leaves, forming fleshy scales swollen with food material; these surround and protect the bud, which when it grows produces green leaves and a terminal flower-shoot; growth is continued by axillary scale-leaved shoots situated among the scale leaves, which in due course themselves produce green leaves and flowers. These compact food-charged stems take up their position well below the ground, out of reach of intense heat or drought, and during the favourable season send up rapidly into the air their leaves and

flowers, after which they remain dormant till the following year.

It has been seen that unless a plant is a parasite or saprophyte, using as food ready-made organic material, it is necessary that it should possess a sufficient expanse of green (*i.e.*, chlorophyll-bearing) tissue for the purpose of assimilation. This is the essential function of the leaves; but before leaving the study of stems it should be pointed out that they usually assist, and sometimes entirely replace, the leaves as organs of food-manufacture. We have seen how in dry places—whether physically dry, from direct scarcity of water, or physiologically dry, owing to reduced activity on the part of the plant due to unfavourable conditions, such as obtain in cold regions, or on poisoned ground like salt-marshes or bogs—leaf surface tends to be reduced, to avoid excessive loss of water. In such plants as the Cacti, and the Euphorbias which so closely mimic the cactus form, this reduction is carried to its limit. Leaves are absent, and the stems, greatly swollen so as to store water, take up the process of assimilation, and perform it satisfactorily. In more rapid-growing plants, a sufficient area for assimilation may be obtained by abundant branching, as in the Gorse, in which leaves are present only in the seedling stage. In the Brooms (*Genista*) the leaf-development is often weak, but the stems sometimes make up for this by bearing green flattened wings. In the Spanish Broom (*G. sagittalis*), a straggling shrub inhabiting dry places in south-west Europe, the few ovate hairy leaves, produced in spring, soon fall; but the slender branches bear several (two to four) broad green wings, which act as

leaves, and persist for a couple of years, when they pass away, leaving slender, round, brown stems. In

FIG. 20.—GENISTA SAGITTALIS. ½.

our native Broom (*Sarothamnus scoparius*) a similar modification may be observed, though of less degree.

Sometimes stem-structures assume a very leaf-like form, as in the Butcher's Broom (*Ruscus aculeatus*), where the ultimate branches are ovate and quite flat, and might be taken for true leaves but for the fact that they bear on their surface flowers, and subsequently berries. The leaves themselves are in this plant reduced to minute scales, and from their axils these flattened branches spring. In fact, where leaf reduction takes place, the process of assimilation is often shared in varying degree by the leaves, the stipules, and the stems. Among our native plants, as, for instance, in the Leguminosæ and Rosaceæ, the reader may find for himself many interesting examples for examination.

But the large majority of the Seed Plants bear well-developed leaves, to which the process of assimilation is practically confined.

Leaves vary surprisingly in size, shape, and arrangement, features which are closely related to the characters of the stems which bear them, the object being the most advantageous display of the chlorophyll in relation to the light-supply. In general they naturally take the form of a broad thin blade, protected as may be necessary against extremes of weather, and guarded against the obvious danger of being dried up by a thin waterproof covering or cuticle outside the epidermal layer of cells. In leaves we find the same beauty of mechanical construction as is seen in stems. The problem is again that of securing maximum efficiency with minimum expenditure of material. To give as great a surface as possible, the leaves are as broad and thin as is consistent with safety, the question of damage by wind being an important control-

ling factor. The veins, or vascular bundles, act efficiently as strengtheners of the thin surface; to prevent tearing at the leaf-edges the veins are often looped along the margin; while in indented leaves the extremities of the indentations are strengthened with special tissue. When one surface of the leaf faces the sky, as in most cases it does, this surface is strengthened against the weather, and the stomata are arranged mostly on the lower surface. Where occasionally the leaves hang normally in a vertical position, as do the mature leaves of the Gum Trees (*Eucalyptus*), both sides are protected, and the stomata are borne on the two faces equally. In the Water Lily, again, whose leaves float, the upper face, which alone is exposed to the air, bears the stomata, which are present in unusual numbers—nearly 300,000 to the square inch; the leaf surface is toughened to resist rain and wind, and waxy to prevent water from lying on it and so interfering with transpiration. The presence or absence of a leaf-stalk, again, is often clearly related to the light question. In the Water Lilies the continued lengthening of the elongated petiole causes the older leaves to float clear outside of the younger ones. In many biennial herbs, where food is stored up during the first season in preparation for the flowering effort in the second, a similar arrangement prevails—note the leaf-rosettes displayed by Spear Thistle (*Carduus lanceolatus*) and Herb Robert (*Geranium Robertianum*), as also especially in winter by perennials like the Dandelion (*Taraxacum officinale*) and Ribwort (*Plantago lanceolata*). Where stems spread horizontally, as the lower branches of trees, the leaves are arranged more or less in one

plane, in such a manner that overlapping is reduced to a minimum (Fig. 21). This is well seen in horizontal branches of the Elm and other familiar trees. In the plant chosen for illustration (*Azara microphylla*, a Chilian shrub), an interesting arrangement

FIG. 21.—AZARA MICROPHYLLA. $\frac{1}{2}$.

obtains. One of the pair of stipules which subtends each leaf is itself leaf-like, and stands at an angle, so that a mosaic is formed of true leaves (the larger ones) and stipules (the smaller alternating ones). On all stems the leaves are arranged not at haphazard, but according to definite rules. Sometimes they

are grouped in circles (*whorls*) at certain points of the stem, as in the Bedstraws; often in opposite pairs, arranged criss-cross, as in the Sycamore; most frequently in a series of spirals. The result in all cases is the same—it allows of as great an

FIG. 22.—LEAF OF WEINMANNIA TRICHOSPERMA. $\frac{1}{1}$.

interval as possible between any leaf and the one immediately below or above it, and gives to all an equal share of light. The indenting of leaves, as in the Sycamore, or their division into separate segments, as in the Ash and Horse Chestnut, is of un-

doubted advantage as allowing light to pass through to lower layers of leaves; it also materially diminishes the danger arising from excessive wind-pressure. In the former case there is often a wide space between the divisions of the leaf; but where this is not required, the parts of the leaf fit closely together, to secure a maximum of surface. A particularly pretty example is seen in the Chilian shrub *Weinmannia trichosperma* (Fig. 22). Here, to avoid the loss of the area between the leaflets, the mid rib steps in, developing triangular wings which fill the spaces. It might be objected that the plant might have saved itself much trouble by producing, while it was about it, a simple undivided leaf covering the whole area. It is difficult to answer such suggestions. Probably the present form of the leaf best meets the conditions of wind, rain, and light under which it lives. Possibly its present form is bound up with its ancestral history. "It must be acknowledged," says D. H. Scott, "that nothing is more difficult than to find out why one plant equips itself for the struggle with one device and another attains the same end in quite a different way."

During cold and tempestuous weather the presence of leaves may be a danger to the plant rather than a help; and where seasonal variations are such that strongly contrasted periods of favourable and unfavourable weather occur, such as the summer and winter of our own climate, many plants have adopted the device of shedding all their leaves: this is especially characteristic of the largest plants (the trees), which would naturally suffer most from unfavourable weather. The fall of the leaf is accom-

plished by means of the formation of a transverse layer of corky tissue across the base of the leaf-stalk, combined with a weakening of the layer of cells immediately above. Prior to the perfecting of these arrangements for dropping the leaf, all the useful materials in it are withdrawn down the stem, so that only an empty skeleton is shed; the scar that remains is not an open wound, but is well protected by the corky layer before mentioned.

Stipules and bracts need not delay us in this sketchy survey of plant organs. They are leaves, generally of rather small size, placed, the former one on either side of the point where a leaf-stalk emerges from the stem, the latter singly below a flower; they are present in some plants, absent from others. They function in the same way as ordinary leaves, and in the earlier stages of growth are of use protectively. Occasionally the stipules exceed or even replace the leaves, as in the native *Lathyrus Aphaca*, where the leaf is reduced to a tendril, and the pairs of broad "leaves" are really the stipules. The bracts, in their turn, sometimes take on the "advertisement" function of the petals, as we have already seen (p. 87) in the case of certain Euphorbias.

The leaves of water plants offer several points of interest. Where they are entirely submerged, and, protected against the drying influence of wind and sun, they are of filmy texture. Broad blades are seldom met with, the leaves being usually either finely dissected or strap-shaped. The floating leaf, on the contrary, as already described in the Water Lily, is strongly built up, to withstand wave action and rain; it is usually broad and entire, which simplifies the

problem of avoiding submergence; and the stomata are confined to the upper side, which alone is in contact with the atmosphere. Those water plants which

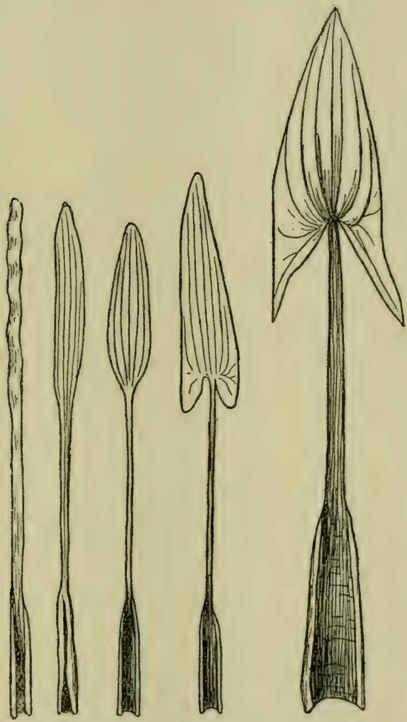


FIG. 23.—SPRING SUCCESSION OF LEAVES OF MATURE PLANT OF ARROW-HEAD (SAGITTARIA SAGITTIFOLIA). $\frac{1}{3}$.

raise their leaves into the air, on the other hand, have leaves of a variety of shapes, which in most respects approach those of land plants. An interesting pro-

gression of leaves illustrating all three stages may be watched in spring in the Arrow-head (*Sagittaria sagittifolia*). The first leaves produced are entirely submerged, and conform to the usual ribbon shape and delicate texture. Those which follow float on the surface. In them the lower part is contracted into a flaccid winged petiole, the upper part being expanded into an oblong floating blade with a waxy surface to keep the leaf dry on the upper side. These in turn give way to the characteristic aerial arrow-shaped leaves of summer, which approach in character the leaves of land plants, and are borne on stout, stiff petioles capable of resisting wind and wave.

Coming now to FLOWERS, it is possible here to refer only to a few macroscopic or "naked-eye" characters and modifications; the full study of the flower and its essential functions being a matter for the laboratory and the high-power microscope, as very minute structures are involved. As briefly described in Chapter IV., flowers are groups of modified leaves arranged mostly very close together at the ends of branches, the tip of the shoot being often expanded into a *receptacle* (very well seen in the Compositæ—*e.g.*, Dandelion) for the accommodation of the crowded floral leaves. Just as the foliage leaves have become modified to carry on to the best advantage the process of assimilation, so the different series of floral leaves are specially adapted to their several functions. The sepals, which compose the *calyx*, having usually a protective rôle, in most cases enclose the young flower with a tough envelope; they usually retain their primitive green colour, and take part in the process of assimilation. They may drop off as

the flower opens (*e.g.*, Poppy), or wither as the petals wither, or remain fresh until the fruit is ripe. Sometimes, as in many Ranunculaceæ (compare *Anemone*, *Caltha*, *Helleborus*), they take on the advertising rôle usually assigned to the petals, being large and coloured, while the petals themselves are minute. In the Monocotyledons they usually join with the petals in adorning the flower. The next whorl, lying inside (that is, above) the sepals, is formed of petals, constituting the *corolla.* The connection of colour and form of petals with the visits of insects, and their relative insignificance in wind-pollinated flowers, has already been referred to (p. 81). The marvellous variety of colour and form observable in the corolla has for its main object the attracting of insects to the flower. The petals have departed much farther from the ordinary leaf-form than the sepals. They assume brilliant hues of every tint, the pigment being due either to colouring matter dissolved in the cell-sap (pinks and blues) or to small coloured solid bodies (*chromoplasts*) contained in the cells (reds and yellows). Chlorophyll being absent, the coloured petals do not assist assimilation: they are purely advertisements, though incidentally they often fulfil a useful protective rôle for the important organs which they surround. In this latter connection their sensitiveness to changes of light and temperature, which causes them to close in dark or cold weather, is a very familiar phenomenon; as is also the excellent protection which they provide in flowers such as those of the *Labiatæ*, where, fused together into a tube, they form a kind of cave in which the stamens and pistil nestle securely.

An exceptional use of petals, where indeed they are used for the purposes of advertisement, but to secure the dispersal not of the pollen, but of the seeds, is illustrated in Fig. 24. In the genus *Coriaria* the staminate and pistillate organs are borne on separate flowers. The flowers of both kinds are small and inconspicuous. But in the "female" flowers the

FIG. 24.—FRUIT OF CORIARIA JAPONICA. $\frac{1}{1}$.

petals persist after flowering, and, becoming fleshy and comparatively large, enclose the seed in a pulpy berry-like envelope, which no doubt serves the same purpose as a true berry in securing seed-dispersal by being devoured by birds. In *C. terminalis*, which comes from the Himalayas, the "ripe" corolla is bright orange; in *C. japonica*, from Japan, it is at first coral-red, and when mature velvet-black.

The *stamens*, which form the next ring (sometimes a double ring or a close spiral), are much less leaf-like than the sepals or petals, yet there can be no doubt that they are descended from leaf-shaped organs; this is especially clear from the study of certain primitive fossil types, in which the corresponding organs which bear the pollen are actually leaf-like. In most of the present-day Seed Plants the stamens conform to a uniform type—a slender stalk (*filament*) bearing a head (*anther*) containing four chambers, in which are produced *pollen grains*, which escape when the flower is mature by the splitting of the enclosing walls. The ways in which the pollen is then conveyed to the pistil of other flowers have been referred to briefly on a previous page (p. 82). The stamens in many flowers are few, and their number usually bears a relation to the number of the other floral parts; in other flowers, for instance Rose and St. John's wort (*Hypericum*), they are of large and indefinite number. The peculiar arrangement of the pollen in Orchids has been already noted (p. 94).

The final ring of modified leaves in our typical flower constitutes the *pistil*, formed of one or many *carpels*, the essential structure of which has been touched on already (p. 82). In the present place it is desired only to point out some of the leading modifications which the pistil undergoes, so that its structure as seen by the naked eye may be understood. In the simpler forms of carpel, the affinity to leaves is still evident, though in forms of pistil made up of a number of carpels this may be very difficult to trace. With the Pea, for instance, we may begin, as presenting a very simple example. Take an oblong leaf like

that of a Laurel, and fold it down the mid rib till the two edges are in contact. There is our pea-pod complete. The young seeds, or *ovules*, are borne in a row along the mid rib, a very usual arrangement. Examine next the young fruit of a Columbine (*Aquilegia*). Here there is a group of five separate erect carpels, but each is essentially like a pea-pod in structure. Compare the fruit of a Saxifrage. This clearly consists of two carpels which are grown together save at the tips, where the two styles stand out like little horns. From this we may go on to other pistils in which several carpels are completely fused together. Next, the compact body thus formed may be sunk down in the expanded top of the stem (the receptacle). Or the other parts of the flower—sepals, petals, stamens—may in their lower part be fused with the walls of the pistil, and may thus appear to spring from the top of it. In such cases the structure of the flower may easily be wrongly interpreted, and reference to a work on systematic botany is necessary if pitfalls are to be avoided. It is indeed to be noted that in flowers, as in other parts of plants, complicated structure or multiplication of parts is not necessarily an indication of advanced evolution; on the contrary, it is often indicative of a primitive condition. Just as in machinery or in organized human effort simplification often accompanies improvement, so it is with plant structures. Many of the more primitive types of flowers, such as Buttercups or Water Lilies, have a multitude of petals or stamens or carpels, while in many of the most specialized, such as Composites or Campanulas, the number of parts is much reduced. The primitive wind-pol-

linated flowers produce large quantities of pollen; in those which have adopted the improved method of utilizing insects, the amount of pollen is much less; in the highly specialized Orchids, a most successful group, the pollen is reduced to two small bundles.

Once the act of pollination is effected, the duty of the petals and stamens is finished, and they generally fade. The sepals often remain, as in the Rose. By the growth of the pollen tube from the stigma into the ovary, fertilization is effected, and mature seed is produced. The fruit—that is, the seed and its coverings or appendages—offers the most varied forms of any of the plant organs—compare Hazel, Strawberry, Pea, Apple, Cranesbill, Dandelion; the variety is endless. Many of these forms are connected with the means by which seed-dispersal is effected: this subject has been touched on in Chapter III. But in numerous instances we can no more assign a reason for their beautiful or fantastic forms than we can account for the infinite variety of shape assumed by leaves and flowers.

Summing up, then, what has been sketched in this chapter, we must think of our plant as a very complicated and wonderful machine, of which the terrestrial Seed Plant is the highest expression. Water is the basis on which its activities are founded—the currency in which all business is transacted. The amount of water contained in a growing plant is seldom realized. Even solid timber, when growing, is half wood, half water. A fresh lettuce loses 95 per cent. of its weight if the water is driven off by drying. Living in an aerial medium which tends to deprive it of moisture continually, and which furnishes water

to the soil only intermittently in the form of rain, and often in sparing quantity, the plant envelops itself from end to end of its exposed portions in a waterproof cuticle; the only openings in its surface layer are the spongy tips of the root hairs on the one hand, and in the stomata on the other. These minutest of openings—so small that the number on a square inch of leaf surface often far exceeds a hundred thousand—might prove danger-points were they not most jealously watched over. But each is provided with a pair of guard-cells ready to close the opening at any moment; and where drought threatens, the whole of the stomata are found in concealed positions. An ample pipe-system extends from root, through stem, to leaf, but it does not communicate directly with the openings at either end. All material, whether liquid or gaseous, absorbed or given out, has to run the gauntlet of the living cells, which are jealous watchmen, and allow only selected substances to pass through them. The crude building materials and food materials are assembled in the leaves, where in cells spread out to the light the chlorophyll is massed. Under the microscope, the chlorophyll is seen to be located in minute granules embedded in the semi-fluid contents of the cells. Well may we gaze in wonder at these tiny green specks. Each is so small that although a couple of hundred of them are often present in each cell, they occupy but a very small proportion of its volume. The cells themselves are of microscopic size. The chlorophyll itself occupies only quite a small portion of the corpuscle in which it is immersed; yet on its activity as spread in this infinitesimal quantity through the leaves the whole organic

world, animal as well as vegetable, depends.* Utilizing the energy which comes through space from the sun, it builds up organic compounds; from the energy thus stored comes all the varied life and vital movement which fill our world—the opening of flowers, the hum of insects, the march of armies, and our own restless thought; while its work in the distant past, laid by in coal and oil, warms our houses and drives our trains, factories, and steamships.

The work of the living chlorophyll accomplished, the food materials produced by its agency are sent by the pipe-system to all parts of the plant, for present use, or to be stored in root, stem, or leaf for future requirements.

Nor is our plant the passive, motionless thing that it may appear to be in comparison with animals and their larger movements. Active motion, local and general, though usually of relatively small amount, accompanies all plant-growth. Throughout root, stem, leaf, and flower transference of material is going forward vigorously. The root hairs and stomata are working at high pressure; the chlorophyll never ceases its activities while daylight lasts. Externally, the growing branches, leaves, and flowers also display incessant movement, sweeping the air in small circles, or in the case of climbing plants in curves of considerable amplitude. Alterations of illumination or of temperature produce other movements—bendings towards or away from light, the drooping of leaves and closing of flowers at nightfall, and so on.

* To be accurate, certain groups of Bacteria, the lowest forms of organized life, must be excluded. They appear capable of building up their bodies directly out of inorganic substances.

All these phenomena of growth and movement culminate in the production of flowers, and in the remarkable developments by which, through the agency of pollen and ovule, a new generation is produced.

CHAPTER VI

PLANTS AND MAN

THE appearance of man upon the Earth is an event of very recent occurrence, not only in terrestrial history, but in the history of organic life in the world. In the life-story which began somewhere in far pre-Cambrian times, the record of the whole of human activities occupies but the last paragraph of the last chapter. For millions of years—ever since the larger animals first abandoned the aquatic haunts of their ancestors and took to a terrestrial life—creatures great and small, of myriad kinds, including huge reptiles and amphibians, and later on a crowd of birds and mammals, have fed on land plants, without effecting any profound changes in the appearance of the mantle of vegetation which covered so much of the Earth's surface. It has been left for the human race, in the course of the few thousand years that have elapsed since it emerged from an existence comparable to that of the beasts and birds, and learned the arts of peace and war, to effect such sweeping changes in terrestrial vegetation over wide areas, that its influence in this respect requires a separate chapter for its consideration.

The changes referred to are largely—though by no means wholly—due to the requirements of the art of husbandry; and to the history of agriculture we may

look for information as to the time and place and nature of man's conquest of the surface of the globe. At the period of the earliest human civilizations, such as those of Egypt and Mesopotamia, the domestication of plants and animals had already reached an advanced stage. Its origin lies far behind the historic period. We can picture in imagination the time when in all inhabited parts of the globe man wandered with no fixed abode, seeking food when he was hungry, and making no provision for the morrow. Residence in a spot which afforded a valued supply of food, such as an abundance of buckwheat or millet or dates or bread-fruit, might lead to a desire to encourage the growth of such useful plants by protecting them and their offspring; following on which might arise the practice of assisting their growth, and thus eventually of cultivating them. Selection of the most productive strains would gradually follow, and barter would cause the spread of useful plants over wider and wider areas. We can picture development from such rude beginnings into the regular cultivation of the soil and the enclosing of the cultivated areas for their protection. It is clear that such practices would not readily arise among nomadic tribes, nor among those inhabiting forest regions where the ground was densely covered by trees. An abundance of animal food would produce a race of hunters rather than of tillers of the soil; and as for forest regions, they are unsuitable for human development; forest races have never been pioneers of civilization. Before agriculture—indeed, before civilization in any form—could make much progress, a settled life was necessary, free from migrations in search of food or

for the avoidance of enemies. Hence the earliest civilizations tended to arise in areas which were protected by natural ramparts from the irruption of rival tribes. Egypt had the desert on three sides, and the sea—an impassable barrier to early peoples—on the fourth. The valleys of the Euphrates and Tigris presented similar features. In both areas rich alluvial soil offered a full reward to attempts at agriculture, and the alternation of summer and winter encouraged the making of provision for the non-productive period by the taking advantage of the period of growth: conditions not present under the "endless summer skies" of Tropical lands, where an easy and perennial food-supply tended against the development of industry.

The basin of the Mediterranean—the cradle of the earlier Western civilizations from the time of Egypt down to Rome—was, then, also the cradle of European agriculture. These lands, with their wet winters and dry summers, the latter inimical to the development of tree growth, lent themselves to cultivation more readily than the great forest-belt which lay to the northward, sweeping across Europe from Britain to the Urals. Although there is clear evidence that grain was cultivated in Europe as far back as the Neolithic Period (say 7,000 to 5,000 B.C.), it seems established that when Roman agriculture stood at its perfection the peoples to the north were still mainly nomads, dependent for their food-supply on their flocks or on the chase. In Britain, Cæsar found corn grown in Southern England, but the centre and north were largely forest land tenanted by tribes living on flesh and milk, and clothed in skins. The vigorous

colonization of the Romans may well have been accountable for the introduction into Britain of many of the farm plants still grown there. The wars of the next fifteen hundred years on the one hand, and the spread of agriculture on the other, caused the steady destruction of the forests, till at length England and Central Europe began to assume their present appearance. The draining of marshes and fens, the enclosing of land, went on steadily, and to a slight extent is going on still; within recent years, the European War has resulted in the disappearance of many of the remaining woods, and in the breaking up of fresh land.

From the point of view of the botanist, agriculture consists of the destruction of the plant associations which for some thousands of years have occupied the ground, and their replacement by other plants which are useful to man. The natural plant associations being the result of the survival of the fittest through a long period of time, while the farmer's crops represent plants which do not grow naturally on the ground, nor often indeed in the country (while they are frequently artificial forms unable to reproduce themselves), it follows that the latter cannot compete with the former, and can be maintained only by the most careful protection. The native plants are always striving to reoccupy their legitimate territory, and the farmer is incessantly engaged in trying to keep them out. Agriculture, indeed, has been defined as "a controversy with weeds." Incidentally, the suppression of the natural flora allows many weaker plants an opportunity of which they are not slow to take advantage. These may be natives, but are often

annuals which have followed the spread of farming operations, or which are directly—though unintentionally—introduced by man as impurities in the seed which he sows.

Let us look a little more closely into the question of profit and loss in our flora resulting from agriculture. In the first place, whether the ground is tilled or grazed, the woodland which primitively occupied so much of it disappears. The plough and the scythe are fatal to all seedling trees. Little less fatal is the browsing of cattle and sheep, and even in rough pasture only thorny plants like Whitethorn and Gorse may be found battling successfully for a lodgment. Where woodland is used for pasturage, the delicate shade plants—Anemones, Wild Hyacinths, Primroses—soon die out. No young trees appear on the grazed surface, though hundreds of thousands of seeds may be shed annually over the ground. In the course of time the present trees will die, and only grass remain. How different is it where cattle are excluded and the scythe unused! Among the grass young trees spring up everywhere, and in the woods a dense undergrowth of saplings sheltering a varied shade flora makes its appearance; regeneration of the natural woodland proceeds apace.

Natural grasslands, if undisturbed, possess a flora which has been built up during a long period of time, and which, like all purely natural plant associations, represents a delicate balance between its many constituents, which often include rare and shy species. If such land be once broken up, its flora will probably never again resume its former composition even if allowed to regenerate during a long series of years,

for the alteration in the old substratum caused by its being turned over and mixed introduces new edaphic (*i.e.*, soil) conditions which will not entirely pass away. As regards grazing, likewise, when land is pastured up to or near its full capacity, as is generally the case on enclosed areas, the weaker and often more interesting members of the flora tend to disappear. In primitive times all grasslands had, of course, their natural grazing inhabitants—in our islands deer of more than one species, sheep, and smaller creatures such as rabbits and geese—and so a total exclusion of grazing animals now would no more tend to reproduce exactly the flora of pre-husbandry days than does the excess of herbivores; but the present heavy stocking of the land is to be deplored by the botanist, even as it is rejoiced in by the economist. The more vigorous plants, and especially those which propagate themselves largely by vegetative means, survive, or even increase owing to the augmented food supplied by the manure which the animals provide; but many species fail to ripen seed, being either eaten or trampled; the rarer Orchids, strange ferns like the Adder's Tongue (*Ophioglossum vulgatum*), and Moonwort (*Botrychium Lunaria*), and the other choicer denizens of the grasslands, tend to disappear.

Drainage is an obvious cause of loss to our flora. Whole lakes and areas of swamp, with their peculiar and to a great extent natural flora, have disappeared from parts of the country. Some of the most interesting marsh plants of the British flora—such as the two fine Ragweeds, *Senecio palustris* and *S. paludosus*, and the Marsh Sow-thistle (*Sonchus palustris*) —have on this account almost vanished from our

islands, like the Bittern and Great Bustard which are their companions.

Some lakes, again, have been ruined for the botanist by being used as reservoirs. The considerable changes of level which this involves is a thing to which plants are not adapted, and only a few can withstand it, such as the Water Bistort (*Polygonum amphibium*) and the Shore-weed (*Littorella uniflora*), which are equally at home on land or in water, being able to change rapidly their structure and mode of life to suit change of environment. As compared with a lakelet with a natural outlet, a dam with a sluice has always a much reduced and usually quite uninteresting flora.

The proximity of a large town, especially if it is a centre of manufacture, is a notorious factor in the reduction of the native flora : not only by the thoughtless and wanton destruction carried out by its inhabitants, but more subtly by the deposition of soot, and by the poisoning of the air by sulphurous and acid fumes. The higher Cryptogams, such as Mosses and Hepatics, are particularly susceptible in this respect, and vanish along with the more delicate Seed Plants. Mining centres are specially destructive of plant life, since, in addition to other drawbacks, the soil is often buried under masses of excavated material containing poisonous substances. If there is a purgatory for plants, it is surely found in such areas.

Other examples of the multitudinous ways in which human activities disturb and destroy native plant life will occur to the reader—the burning of moors in order to improve them as pasturage; in recent years the tarring of roads, which kills the pleasant wayside herbage and poisons the streams into which the road

drainage is carried; and so on. The indictment is an overwhelming one, and, as said in the first chapter, the flora is now everywhere so altered that we can gain some idea of its original aspect only by a study of isolated fragments and much-adulterated samples.

But if the debit side of the account, as presented by the lover of nature, is heavy, it must not be forgotten that there are many items to man's credit. Though our country's vegetation has lost in scientific interest, it has gained vastly in both economic and æsthetic value by the introduction of useful and ornamental plants from all the Temperate regions of the world; and besides, a large number of species have followed in man's footsteps, and, taking advantage of the disturbance of the native flora caused by his operations, endeavour with more or less success to establish a footing in the country. Before we trespass on the domains of arboriculture, horticulture, or agriculture, under which heads the cultivation of useful or ornamental plants divides itself, some consideration is required of those plants which, quasi-wild, are usually included in accounts of the vegetation under the head of aliens, denizens, colonists, and so forth. These constitute a quite considerable proportion of the total number of species found in any area which has felt the influence of man. For instance, in the county of Dublin, which, owing to its diversified surface—sea-cliff, sands, moorland, woodland, and cultivation—and its favourable climate—the warmest and driest in the country—possesses the largest flora of any similar area (354 square miles) in Ireland, the list of about 760 "wild" plants includes some 170, or over one-fifth of the whole, whose presence is attributable,

directly or indirectly, to human activities. We may compare these figures with those drawn from a study of the flora of Kent, which faces across the Channel towards France just as county Dublin faces across the Irish Sea towards England; both are areas of early settlement and both lie in the main stream of traffic. In Kent we have to deal with a larger area (1,570 square miles), and a larger flora (1,160 species). We find that, of these 1,160 species, 146, or about one-eighth, are set down as owing their presence to man.* And so it is in all the more populous and highly tilled parts of our islands.

This question of alien plants, their past history and present standing, is one of the most puzzling with which the student of our flora has to deal. In the first place, most of them have been in the country for a long time, and the record of their introduction is lost. Next, while many of them are confined to ground disturbed by man, and thus clearly exist under man's protection—however unwillingly that protection may be afforded—others have mixed with the indigenous flora, won a place in the closed native vegetation, and might be ranked as true natives were it not that a study of their general distribution raises doubts as to the possibility of their having arrived in our islands unaided—doubts which their known occurrence in gardens tends to confirm. Take the case of the Yellow Monkey-flower (*Mimulus Langsdorfii*). This has quite established itself in our native flora, in some places ascending mountain streams far into the hills, in others mingling with the rank flora of

* F. J. Hanbury and E. S. Marshall: "Flora of Kent," 1899, p. xxxv.

muddy estuaries. It *looks* as aboriginal as any of the plants among which it grows: but the facts that the genus to which it belongs is American (with a few species in Australia and New Zealand), that it itself is found native in the western States and not in the eastern, and that it has been long cultivated in gardens, furnish convincing proof that it is really an alien. But it is seldom that the evidence is so satisfactory as in this case. More usually the range of the doubtful members of the flora is continuous, extending from regions where they are truly native to others where they are undoubtedly exotic. For instance, many annual plants of the Mediterranean region have followed the spread of agriculture across the former forest areas of Central and Western Europe into our own islands. Plants native in France have been transported into England, and English natives into Ireland; east Irish plants have spread westward—sixty years ago, save for a single record of *P. hybridum*, *Papaver dubium* was the only Poppy known west of the Shannon; now all four British species occur, several of them in many places. The flora of Europe, as pointed out already, diminishes in variety as we pass westward into the outlying areas. Those species whose aboriginal distribution stopped short of the western limit of the land had no doubt a fluctuating western or northern or southern boundary to their range, dependent on temporary conditions. Thus, a hard winter might kill back a plant already at the limit of its natural range, or a warm summer, by ripening abundance of its seed, might result in its slight advance. The general effect of human operations has been to lessen competition and increase

suitable habitats by the destruction of the native vegetation which occupied them, and this has resulted in a general advance of a large number of species. What renders the study of this advance so difficult is the fact that on all disturbed land the truly native plants which have been ousted are striving side by side with the immigrants to regain their former territories; and it is now often very difficult to disentangle them: to separate the sheep from the goats. If only we could have had a Watson's "Topographical Botany" written five thousand years ago, before our restless race began to mess up the vegetation!

However, as has been said, what we have lost on one side we have gained on another. On every side bright immigrants meet the eye. Our old buildings and quarries often blaze with the Red Valerian (*Kentranthus ruber*) and Wallflower (*Cheiranthus Cheiri*); in fields Poppies of various kinds, Corn Cockle (*Lychnis Githago*), and Corn Blue-bottle (*Centaurea Cyanus*) add a glory to the rich green or gold of the cereals; dry banks and gravelly places are decorated with species of Melilot (*Melilotus*), Chamomile (*Anthemis*), Knapweed (*Centaurea*), and many others. The flora of harbours and docksides is often as cosmopolitan as the sailors of the ships by whose agency it came there; and the unfamiliar weeds—the gipsies and tramps of the plant world—which we encounter on roadsides, rubbish-heaps, and railway stations lend an additional interest to our botanical rambles.

Turning now to the plants which are used by man, it may be pointed out in the first place that the human race obtains much more, whether of profit or of

pleasure, from the vegetable than from the animal kingdom. Flesh, whether derived from mammals, birds, or fishes; wool, silk, leather, oils, and so on, bulk much less than the grains, vegetables, fruits, timber, fibres, fodder plants, and other vegetable products which we use in our daily life. On the æsthetic side, again, while the beauty of birds and insects is a source of frequent delight, flowers play a part in daily life that the more delicate and sensitive animals can never do. Again, in the number of different species used, whether for profit or pleasure, the plant world takes precedence. This is especially the case as regards our farms and pleasure grounds, plants lending themselves much more readily to domestication than animals do. And so a suburban house may have a hundred or a thousand different plants in kitchen garden and flower plot, orchard, and shrubbery, while its animal dependents consist of a horse, a couple of dogs, a cat, some fowl, and a canary. So again a Botanic Garden may easily possess as many thousands of different species as a Zoological Garden contains hundreds.

This army of plants which human beings collect about themselves may be grouped under two categories—useful and ornamental. On a previous page (p. 136) a suggestion has been made as to how the cultivation of useful plants may have arisen. As now practised, this industry is the largest in the world, and with the growth of means of transport has ceased to be only or even mainly of local importance: we use every day wheat from Australia, rice from China, tea from India, cotton from the United States, timber from Norway. In some cases, as in the last, these materials are harvested as they occur in the wild state,

but in the majority of instances the plants are not merely conserved, but cultivated; cultivation has led to selection of the best varieties; and continued selection has resulted in the production of forms often very different in appearance from the wild plants from which they originated. We cannot *create* new forms; but by taking advantage of the innate tendency to vary which all plants display—some to a much greater degree than others—and by raising, generation after generation, the seeds of those individuals in which a certain abnormal feature is best displayed, we can produce an artificial race in which the selected character may be developed to an extraordinary degree. But we have not by this means produced a new species. Seedlings of such plants will tend to "throw back" towards the original form; we can preserve or improve the special characters only by continued selection; if allowed to grow and seed unchecked, most of such plants will revert to the natural type in a few generations. Often this reversion is so rapid that seeds are useless for cultural purposes, and it is only by cuttings or graftings—that is, by growing parts of the original possessor of the required characters—that constancy can be maintained; this is what is usually done in the case of fruit-trees, Roses, Pansies, and so on.

Equally efficient in the hands of the cultivator has been another method of producing new forms—namely, hybridization. If the pollen of a plant be transferred to the stigma of a related species, offspring is often produced; and the product is a batch of plants intermediate in characters between the two parents, and generally uniform in appearance. Should these

be crossed again, a heterogeneous offspring is the result, displaying a variety of characters inherited from one or other original parent. The crossing of varieties, native or cultivated, has the same result. Hybrids occur in nature, but not very frequently. Insects visiting flowers are well known to confine their attention to a great extent to one species at a time, so as agents of hybridization they are not efficient. Again, many hybrids do not produce fertile seed, so that if they arise by natural means they are not perpetuated. In the garden, hybridizing has been resorted to largely; but its practice is not so ancient as the method of producing improved breeds by selection.

The cultivation of specially selected forms is certainly of remote origin, and probably goes back to the earliest days of agriculture: of early date, too, is the introduction into regions where they do not occur naturally of plants desirable for their use or beauty. The records of the cultivation of the Vine, for instance, go back for five or six thousand years in Egypt. Two thousand years ago Pliny writes that ninety-one principal forms could be reckoned in his day, though " the varieties are very nearly as numberless as the districts in which they grow." Theophrastus, three hundred years earlier, discourses learnedly of the different kinds of cultivated Figs, etc., and their superiority over the wild kinds. These and other authors make frequent mention of plants introduced into Greece or Italy from the East for their usefulness or their pleasing qualities. Nowadays, the number of species cultivated, the innumerable forms of these which are grown, and the wide distribution

which these forms have attained, have resulted in the cultivated flora of a country like England being, so far as the higher plants are concerned, much larger than the native flora, even when all the plants which are grown under glass are left out of consideration.

In the case of plants of economic importance, the usual aim of selection has been increase of size or productiveness of the parts which are useful. In some instances selection has taken several directions inside the limits of a single species, as in the forms of Cabbage, which are all the offspring of *Brassica oleracea* (Fig. 25), a seaside plant of Western and Southern Europe, and are mostly creations of comparatively recent date. The Cauliflower has been produced by increasing the size of the inflorescence; White Cabbage by promoting leaf production; Brussels Sprouts by encouraging the development of axillary shoots; while a form with a tall and woody stem is made into walking sticks. More often we find a species developed along a single line. For instance, the tendency to store food materials in a fleshy tap-root has been developed in the case of Turnip, Beet, Carrot; the fleshy scale-leaves which form bulbs have been exploited in the case of the Onion; increased stem-growth is promoted in Asparagus; increased leaf-growth in Spinach and Lettuce; while by the development of seeds and fruits of many kinds artificial selection has supplied us with the foods on which the human race mainly subsists. The most important of all these last are, of course, the different grains, which are the seeds of grasses of various genera—*Triticum* (Wheat), *Hordeum* (Barley), *Secale* (Rye), *Avena* (Oat), *Panicum* (Millet), *Oryza* (Rice),

Zea (Maize). The value of these to the human race is incalculable, and some of them have been in cultiva-

FIG. 25.—WILD CABBAGE (BRASSICA OLERACEA). $\frac{2}{3}$.

tion for at least five thousand years. In some of them, indeed, the native form is now unknown, the improved

varieties alone having been preserved by the care of man. The Wheats are a case in point. While a wild grass growing in Palestine has been quite recently identified as the probable source of the Hard Wheats, the native parent of the Soft Wheats is unknown. That productiveness has in all cases been much increased by long selection there can be no doubt; it may be pointed out that several species of *Triticum*, *Hordeum*, and *Avena*, allies of the Wheat, Barley, and Oat, are included in the native British flora, but they are useless as producers of grain.

Nowhere is the effect on plants of selection and cultivation seen better than in our native fruit-trees. We have only to compare the size, flavour, and almost endless variety of apples and pears with the fruit of the wild stock of these two species—the Crab (*Pyrus Malus*) and Wild Pear (*Pyrus communis*) of our hedgerows—to realize how much has been accomplished. In garden flowers, also, we see most striking results of continuous selection. By taking advantage of the tendency of stamens and carpels to change occasionally into petals, and of petals to increase in number, "double flowers" have been effected. When "doubling" is complete—that is, when the conversion into petals is thorough—no seed can of course be produced, and the plants must be propagated by cuttings. Different other slight natural variations, exaggerated by selection and cultivation, have been the source of innumerable "varieties" in our gardens.

Sometimes the natural variation is by no means slight, but of a striking character which the efforts of gardeners have not succeeded in developing further. Take, for instance, the case of fastigiate trees, such as

the Lombardy Poplar (*Populus nigra*, var. *italica*) or the Irish Yew (*Taxus baccata*, var. *fastigiata*). These are freaks or sports, the character being that *all* the branches, not only the leader, tend to assume a vertical position. The Irish Yew originated as a wild "female" (pistillate) seedling found on the hills of Co. Fermanagh about 1780 and never rediscovered. It appears to be a juvenile form, preserving throughout life its seedling characters—a kind of Peter Pan among plants. Of the Lombardy Poplar the origin is not known, but it was no doubt similar. Seedlings of the Irish Yew revert to the ordinary type, and all the Irish Yews in cultivation are pieces of the original plant grown as cuttings. Poplars, like the Yew, bear the "male" (staminate) and "female" (pistillate) flowers on different trees, and the original Lombardy Poplar having been a "male" it also can be propagated only by cuttings—probably seedlings would in any case revert to the usual form.

The reverse of this abnormal erect habit is seen in weeping trees, where the branches for unexplained reasons seek to grow downward. In nature this results in a creeping habit. If planted on a height the branches will deliberately grow downwards towards the ground. Cultivators graft such forms on the top of a tall stem of a normal specimen, with the result that we see in the Weeping Ash and similar gardeners' productions.

Another large group of casual abnormalities is concerned with the colour of leaves. The Purple Beech is a case in point. It was not produced by selection, but arose naturally, no doubt as a chance seedling. In this instance the character is usually

passed on to the offspring, most seedlings having similar purple leaves, though some individuals are green. The peculiar colour is due in this case to a pigment in the epidermis of the leaf; the green chlorophyll is duly present, though its colour is masked by the purple leaf-skin. To a different category belong the "gold" and "silver" variegations which are so much exploited in shrubberies and borders and greenhouses. These spots or stripes or tintings of pale colour on the leaves are due to the lack of chlorophyll in the chromatophores (chlorophyll corpuscles); sometimes to an absence of the chromatophores themselves; and this omission appears to be caused by an enfeebled condition of the plant. Variegated plants are weaker than normal ones, and hence do not tend to survive in nature. But gardeners have protected and propagated a large number of them. When the variegation arises, as it often does, on a branch of an otherwise normal plant, it usually is not reproducible from seed, and must be perpetuated by cuttings. But where it happens with seedlings, it is often more or less fixed, and may be reproduced generation after generation, as in the Golden Elder, Golder Feather, and the marginal-variegated form of Winter Cress (*Barbarea vulgaris*).

Flower colour is not so fixed as leaf colour, for obvious reasons, the green colour of leaves being due to chlorophyll, which is an absolutely necessary ingredient of the leaf if plant food is to be manufactured; whereas flower colour is merely for advertisement, and any pigment can be made to serve. In nature most flowers vary in tint, and some in a marked degree—take the little native Milkwort (*Polygala*),

which may be blue or purple or white. Flowers offer great opportunities, therefore, to the gardener, and by selecting on the one hand and hybridizing on the other every known tint has been reproduced in some blossom. Adding to this the variability in size and shape of petals, and the tendency to "doubling," the flower in the hands of skilful cultivators has been altered almost beyond recognition. Take the Roses, for example, with their infinite variety of form and colour. The bulk of them are derived from a dozen wild species, possessing comparatively small single flowers, white, yellow, or red—*Rosa centifolia, damascena, gallica* (the source of the older Roses), *indica, moschata, odorata, rugosa, Wichuræiana*, with our native *arvensis* and *spinosissima*. By selecting for colour, shape, and "doubleness," both from the species themselves and from the offspring produced by hybridizing one of these with another, what a wealth of beauty has been developed! More than any other flowers, the Roses are the crown and glory of the gardener's art. Well has the Rose been called the Queen of Flowers; but it owes its royal prerogative to man. Nature provided blossoms—elegant, but of no special promise—and a tendency to vary, of priceless value; human skill and industry have done the rest.

CHAPTER VII

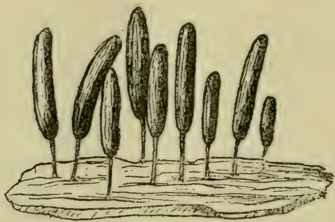
PAST AND PRESENT

THE dependence of animals upon plants for the food by means of which they continue to inhabit the earth, which was pointed out on a previous page (75), shows that the plant world is older than the animal world; but the immense age of both can be appreciated only by a study of stratigraphical geology. The tens of thousands of feet of sedimentary rocks, laid down in slow succession on the floors of ancient seas and lakes, and still reposing layer upon layer, and no less the great gaps in the series produced when, raised into the air, deposition ceased, and thousands of feet of rock were slowly worn away and washed down again into the sea by the action of frost and wind and water, point to periods incalculably remote as measured by the standards which we apply to human history. A few thousands of years measures the span which separates us from the Neolithic Period; but to the geologist a million years is but a convenient unit for expressing, so far as any expression by our time-standards is possible, the huge periods with which he has to deal. And even when we get back as far as the oldest fossils will take us, we are still a long way from having reached the epoch when life on the earth originated. As we work back-

ward and study the fossils of older and older rocks, the multitudinous assembly of plants and animals which fill the world to-day are replaced by other and more primitive forms, many groups approaching each other and merging in common ancestral types. But still, the very oldest fossil-bearing strata contain the remains of organisms already far up the ladder of evolution. The Lamp Shells (Brachiopods), Pteropods, Trilobites, and Worms of the ancient Cambrian rocks have clearly a long ancestral history. Plants are not so abundantly preserved in the rocks as the skeletons and shells of animals, on account of their softer nature; but in the oldest known plants it is again clear that we are dealing with forms by no means primordial. It is the more interesting, then, to note that many very lowly forms of life have come down to us from times immensely remote, and are still present on the earth in abundance, swarming in every sea and in every pond, or nestling in damp crevices of the land; while higher types of immense antiquity still mingle with the crowd of recent Seed Plants, some of them forming noble forest trees. Of especial interest, taking into account the wide distinction which exists between the higher animals on the one hand and the higher plants on the other, is it to find that there are still in existence organisms which are so much on the border-line between these two great groups of living things that they can be referred to one or other only with hesitation, clearly indicating that animal and vegetable life sprang from a common source. Take the group known as Mycetozoa or Myxomycetes. These names alone show the divergent views which men of science

have held regarding them, *Myxomycetes* signifying "slime-*fungi*," while *Mycetozoa* means "fungus-*animals*." These remarkable organisms, of which over 180 species are found in the British Isles, begin life as tiny wind-borne spores. Under suitable conditions of moisture and heat, the spore swells, its wall cracks, and the contents—a tiny globule of protoplasm—creep out, develop a little tail or *flagellum*, which by lashing about propels the pear-shaped *swarm-cell* through the drop of water in which it began life. The organism feeds by catching bacteria and other minute particles of organic matter, which are conveyed into the interior of the little mass of protoplasm and digested. The swarm-cells increase in number by division, and ultimately unite in pairs to form a *plasmodium*, which may, by union with other plasmodia, eventually attain a quite large size. In this naked protoplasmic mass a very remarkable rhythmic movement is set up, the granular protoplasm of the interior streaming rapidly along certain channels for about 1½ minutes, when the motion is reversed and it streams in the opposite direction. The whole mass now creeps about in moist places, usually in the form of a network of branching veins, feeding as it goes, usually on dead vegetable matter. When fully developed the plasmodium creeps out into some more open spot and transforms itself into masses of spores enclosed in spore-cases, which vary much in different genera as regards size, shape, and colour, and are often borne on delicate stalks. When ripe, the spore-cases, or *sporangia*, open, and the spores are liberated into the air to be dispersed by wind and eventually to begin growth on their own

account. This story partakes about equally of incidents characteristic of the life-history of the lower animals and of the lower plants. The fruiting stage and the wind dispersal of the spores recall the arrangements familiar in the Fungi, and are not matched in any section of the animal kingdom; while the creeping plasmodium, devouring food as it goes,



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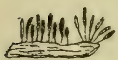

a.

FIG. 26.—A MYXOMYCETE (COMATRICHA TYPHOIDES) IN FRUIT.
a, Natural size; *b*, enlarged.

is entirely suggestive of animal life, and is not paralleled anywhere in the vegetable kingdom. There is no reason to look on the Mycetozoa as a group of animals which have taken on certain plant-like characters, any more than as a group of plants which have evolved certain animal characteristics: we appear to see in them a very ancient group which has come down to us from a time when plants and

animals, as we know them, had not yet become differentiated.

Among plants, as distinguished generally from animals by the production and abundant use of chlorophyll and of cellulose, we have still existing on the Earth a range of forms extending from almost the most primitive organism that we can imagine up to the splendid Seed Plant, specialized in a hundred ways. Every pool, every soil, swarms with bacteria, the lowliest form of life—organisms exceedingly minute, exceedingly simple, and capable of existing under highly diverse conditions both physical and chemical. Thence we can trace an irregular ascending scale through the Fungi, the Algæ, Mosses, Horsetails, Ferns, and Club-mosses, to the Conifers, and on to the highest of the Seed Plants, which exceed in their beauty of structure and complicated life anything that has gone before them. In fact, as Theophrastus says, your plant is a thing various and manifold. And this existing vegetation with its thousand forms is but the present manifestation of the vital activity which has populated the earth during tens of millions of years. The oldest rocks which have been preserved to us in such a condition as to yield remains of plants and animals in a recognizable form are those known as Cambrian, the deposition of which occurred at a period which geologists have variously calculated as from, say, 20 to 100 or more millions of years ago. Yet even at that immensely remote period, life, both vegetable and animal, was already abundant and diverse, as well as highly organized. As Darwin long ago pointed out, the geological record does not go back nearly far enough to allow

us any insight into the evolution of the earlier forms of life. Below the Cambrian rocks, as represented in these islands and in Europe generally, with their well-developed fauna, are tens of thousands of feet of strata which once, no doubt, were sediments at the bottom of the sea, and later on hardened into slates and sandstones in which were embedded remains of more primitive organisms; but these rocks have been so altered during the immense period of their existence by heat and pressure and the other vicissitudes to which the restless crust of the earth is subject that they now present a mass of granite-like material in which all trace of organic life has been destroyed. In America the rocks of corresponding age are better preserved, and have yielded a limited fauna displaying an already advanced stage of evolution. To account for the strange paucity of animal remains it has been suggested that the creatures of these earliest times were soft-bodied, so that after death they left no trace behind. It may be noted that the pre-Cambrian rocks contain beds of limestone and of carbon (in the form of graphite); such beds, in later rocks, are composed of organic materials, the limestones being formed of the skeletons of minute marine creatures, particularly Foraminifera, and the carbon deposits of the remains of plants.

In Cambrian times, then, abundant life springs forth into our vision from the rocks, already, like Minerva, fully armed. The soft plant structures are not well preserved in the older fossiliferous rocks, and hence the fragmentary story of plant life, as we trace it backwards, becomes very obscure, while many types of animals still boldly occupy the stage. At the

earliest period from which plant remains are well preserved and plentiful, in the Devonian rocks, many of the great plant groups are fully developed, the vegetation displaying an abundance and luxuriance comparable to that of the present day. Seaweeds (Algæ), Horsetails (Equisetales), Ferns (Filicales), Clubmosses (Lycopodiales), fill the waters or clothe the land, and Seed Plants are already abundant in the form of the fern-like Pteridosperms, long since extinct. Both as regards adaptation to environment and internal structure a very high degree of specialization has already been obtained. "If a botanist," writes D. H. Scott, "were set to examine, without prejudice, the structure of those Devonian plants which have come down to us in a fit state for such investigation, it would probably never occur to him that they were any simpler than plants of the present day; he would find them different in many ways, but about on the same general level of organization."

In the succeeding Carboniferous Period conditions appear to have been peculiarly suitable for vegetable life, as well as for its preservation in a fossil condition. In the warm, moist climate of those times, many of the races of plants above mentioned attained an imposing size, luxuriance, abundance, and variety; and their remains, fortunately well preserved owing to conditions favourable to slow decomposition, not only furnish a rich heritage for the botanist, but supply the coal, on the energy derived from which our whole modern civilization is built up.

Before the end of the Palæozoic Period the Conifers had appeared, descended possibly from the extinct *Cordaiteæ*. With the advent of the Secondary

or Mesozoic epoch the group of the Cycads, to which our modern Screw-pines belong, rose to great importance, descended probably from the Pteridosperms, and long continued to be a dominant feature of terrestrial vegetation. And then at last in the Lower Cretaceous rocks the Angiosperms, or "Flowering Plants" *par excellence*, both Dicotyledons and Monocotyledons, put in an appearance. It seems probable that they were evolved from Cycads, such as the *Bennettiteæ*, recent researches on magnificent fossil material discovered in America showing striking analogies between certain Cycadaceous flowers and those of such plants as Magnolias, Water Lilies, and Buttercups. Once established, the Angiosperms rose to primary importance in an extraordinarily short time—very possibly owing to the "invention" of insect pollination, which may have arisen at that period. In Upper Cretaceous times the two great groups into which the Angiosperms still fall, the Dicotyledons and Monocotyledons, fairly dominated the flora of the world, as they do at present. Already many types familiar at the present day had appeared, and the woods were filled with Birches, Beeches, Oaks, Planes, Maples, Hollies, Ivies, as they are nowadays.

The record of the rocks during these long periods of time contains not only the story of the rise of the great divisions of the vegetable world, but also of the decline of most of them. A few, like the Pteridosperms and the Sphenophylls, died out completely long ago; but most of the great groups of early days, such as Cycads, Ferns, Horsetails, and Club-mosses, still survive, though shorn of much of their glory.

Races which once formed vast and lofty forests are now represented by a few lowly herbs; and it is difficult to recognize in the tiny *Selaginella* of our moors the representative of the gigantic Club-mosses of Carboniferous days. But certain plants still living retain

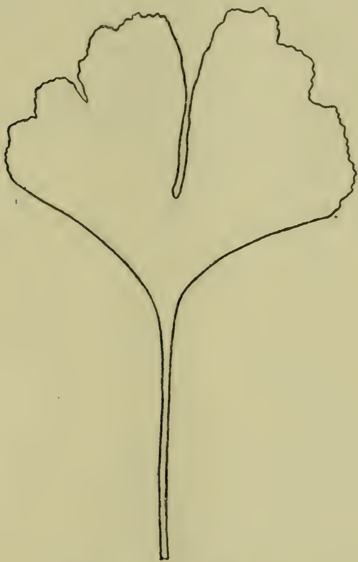

FIG. 27.—LEAF OF MAIDENHAIR TREE (GINKGO BILOBA). $\frac{2}{3}$.

to a great extent the features of their ancestors of the ancient rocks. One of the most interesting of these is the Maidenhair Tree (*Ginkgo biloba*), well known as a sacred tree in the East, and apparently preserved to us through the last few thousand years owing to this custom, as it does not seem to exist

now in a wild state. The genus *Ginkgo* runs back to the beginning of the Mesozoic Period, and its near relatives go back much farther still to the Devonian; the group to which it belongs, *Ginkgoaceæ* (probably descended from the *Cordaiteæ*), attains its maximum in the Jurassic, the "Age of Reptiles," and the existing species or its near relatives saw the Earth teeming with fantastic Saurians, including huge brutes, longer than the greatest whale, which browsed on trees or devoured creatures scarcely less terrible than themselves, while others of different form occupied the sea, and others again of nightmare appearance dashed bat-like through the air. This solitary representative of a great and ancient race is of quite peculiar interest in that it is the highest plant in which is preserved the primitive feature of fertilization by the medium of water, the male cell being endowed with the power of motion, and reaching the egg-cell by means of swimming.

Throughout the Tertiary or Cainozoic Period the dominance of the Angiosperms became more pronounced, and already in the Eocene a flora flourished much resembling in a general way that which now occupies the Earth. Long periods succeeded the Eocene, of which the record is poor so far as plant remains are concerned, at least as regards these countries, but no further great botanical revolutions took place. Through the Miocene Period, with its luxuriant evergreen, subtropical vegetation, we are led to the Pliocene. During this period the climate once again cooled down, and towards the end of it, under conditions very like those prevailing in England at present, many of our familiar species of wild flowers and trees

at length made their appearance—Marsh Marigold (*Caltha palustris*), Sloe (*Prunus spinosa*), Blackberry (*Rubus fruticosus*), Hawthorn (*Cratægus Oxyacantha*), Cow Parsnep (*Heracleum Sphondylium*), Bogbean (*Menyanthes trifoliata*), Gypsywort (*Lycopus europæus*), Sheep's Sorrel (*Rumex Acetosella*), Birch (*Betula alba*), Hazel (*Corylus Avellana*), Oak (*Quercus Robur*), Yew (*Taxus baccata*), Bur-reed (*Sparganium erectum*), Cotton-grass (*Eriophorum polystachion*), Royal Fern (*Osmunda regalis*). The remains of these occur in the "Cromer Forest-bed," a series of estuarine deposits—laid down perhaps by the ancient Rhine—which underlies the boulder-clay cliffs of the Norfolk coast, and forms almost the only plant-bearing beds of Pliocene Age found in the present land area which we call Britain.

And now, just as a point is reached when at length we think we shall see our present British flora emerging fully from the obscurity of the ages, a dramatic interruption occurs, which confuses the record and brings us into difficulties of many sorts, giving rise to controversies which are still far from being settled. The climate becomes suddenly colder, and Europe is plunged into the rigours of the Ice Age. Ice Ages there had been before in the long history of the world. Rocks of late Permian or early Carboniferous times bear ample witness to the existence of great ice sheets extending over wide areas in several continents where temperate or warm conditions now prevail: and puzzling deposits of later age—Cretaceous, Eocene, Miocene—have been interpreted by some geologists as the relics of subsequent Glacial Periods. But these are only distant echoes as compared with the

Quaternary Ice Age, from the effects of which our country and its fauna and flora are still in process of recovery. At the close of the Pliocene Period, then, snow began to extend on the higher grounds, and glaciers to fill the mountain valleys; these conditions were intensified until all Northern Europe, including the British Isles as far south as the Thames valley, lay under a mantle of ice. The plants which occupied the ground were forced southward as the ice advanced, or exterminated by the increasing cold. After long fluctuations of climate, the extent of which appears still in doubt, the ice at length slowly passed away, leaving the surface of our country greatly altered. The ancient soils which had been in process of accumulation since last the land rose above sea-level were swept away, the surface was strewn with materials formed by the grinding down of the hills or the pushing up of sea-bottom material, valleys were choked, rivers diverted, lakes formed by dams of glacial detritus, or by the scooping action of the ice; the whole surface of the country was remodelled on new lines. Into this new land the plants remigrated, and we now view on our hills and plains the results of this repopulation. The difficulties of which I have spoken arise especially in connection with the manner of this recolonization. On a continental area one can conceive of a gradual retirement of the flora before the advance of the ice, and its subsequent re-migration northward into its old haunts as the ice retired. But on an insular area like Great Britain no such line of retreat was open. The ice-free area of Southern England and possibly Southern Ireland does not appear adequate to harbour the crowd of

refugees throughout the cold period. There is good evidence that the time of maximum glaciation was also one of elevation of the land, and possibly this persisted for a while after the passing away of the ice. If this were so, some relief from the congestion might have been afforded to the refugees during the cold period, and an opportunity might have existed when the ice passed away for recolonization across a land surface from the east, since a comparatively small elevation would connect the British Islands with the Continent. But that such an elevation continued for long after the passing of the ice is by no means certain. On the whole, the evidence of general glaciation of our islands as interpreted by geologists almost postulates the extinction within our area of the whole existing flora and fauna, and consequently its reconstruction by immigration when a temperate climate returned. But there is a body of evidence to be drawn from the present and past distribution of the existing plants and animals which is of great importance in this connection. Is this biological testimony in favour of the theory of the immigration of our flora and fauna during the relatively short period which has elapsed since the passing of the ice? To this question different observers have given very different answers. In order to form an idea of the nature of the problem—it is possible here to deal only with the case of the plants—we need to study briefly the composition of the present flora, from the point of view of its origin.

In the first place, it must be recalled that the British Isles are situated on a broad shelf which extends into the Atlantic on the western edge of Europe. In com-

parison with the depth of the adjoining ocean, this shelf is but little below sea-level, and a slight elevation of the land—much smaller than those which have occurred over and over again in recent geological times—would join our islands to Germany, Holland, Belgium, and France. The British Isles are geographically and biologically by no means a separate area, and they have derived their population, both plant and animal, by immigration at various periods of time from the great land area to the eastward. Our present flora proves the truth of this as a general assertion; a study of its constituents shows that it is essentially a reduced continental European flora. As we step from France across to England we lose a number of plants familiar on the French side. As we step again from England into Ireland a further number of plants disappears; and these losses are no doubt due either to an unsuitability of climate on the insular areas, especially the absence of a hot summer, or to the inability of the plants to cross the barriers of sea which have now existed for some time. If the whole of the flora fitted in with this idea of mere reduction of the Continental flora by elimination, the problem would be much simplified. But there are other elements in it which do not harmonize with this conception of simply a general western migration, and which give rise to very interesting problems.

Let us first consider the main mass of our flora, which is closely akin to that of the adjoining parts of the Continent. When we say that it represents a reduced Continental flora we do not imply that it is therefore uniform in its composition throughout the British Isles. We know, on the contrary, by every-

day observation, that it varies much in its constituents. The principal general change is noticed if one travels from the south of England to the north of Scotland. Great Britain extends in this direction for 700 miles—far enough to allow climate to have a marked effect as between its extremities. The flora of Hampshire is very different from that of Caithness or the Orkneys. But both represent in the main the vegetation of that part of the Continent which lies in the same latitude, the Hampshire flora being akin to that of Northern France, the Caithness flora to that of Southern Scandinavia. The likeness is in each case heightened by the fact that the rocks of the respective areas correspond, producing similar soils, which tend to support similar floras. The soft Secondary and Tertiary deposits of Southern England are repeated in the Paris basin and surrounding area, while the ancient gneisses of Scotland are akin to those of Norway. To quote a few instances of this north and south difference coupled with east and west similarity: the Small-flowered Crowfoot (*Ranunculus parviflorus*), White Bryony (*Bryonia dioica*), Water Violet (*Hottonia palustris*), Yellow-wort (*Blackstonia perfoliata*), and Black Bryony (*Tamus communis*), all widely spread throughout England and Wales, die out in or about the Lake District, and are absent from Scotland; the Scale Fern (*Ceterach officinarum*) gets farther north—about half-way up Scotland—before it disappears; other plants again, widespread in the south, die out before the Mersey-Humber line, or even the Severn-Thames line, is crossed. On the Continent, the plants enumerated are mainly southern in their range. All occur widely in Central and

Southern Europe, but from Scandinavia most are absent, and the rest are rare. On the other hand, some characteristic Scottish species cease as we come southward—the little *Primula scotica*, for instance, is confined to the northern extremity of Scotland; the Chickweed Wintergreen (*Trientalis europæa*) ranges only as far south as Yorkshire; and the beautiful Globe Flower (*Trollius europæus*), so characteristic of northern pastures, creeps southward as far as the Severn. The first of these is on the Continent confined to Scandinavia; the others, though found in France, etc., are characteristic of the hilly regions there, and are much more abundant farther northward.

Next to this north-and-south change, due to climate, we may notice an east-and-west change, due partly to climate, but more perhaps to elimination, for in passing from France to Ireland we have to cross two barriers of sea. The climatic change is not unlike that experienced in going from south to north. We leave a dry climate (rainfall under 25 inches a year) for one of increasing wetness, a warm for a cool summer, a colder for a milder winter.

The chief difference between the extreme west of the British Isles and the extreme north lies in the warmer winter of the former, frost being almost unknown in the milder spots. But the general similarity of northern and western conditions as opposed to eastern and southern leads to a fusing of the northern and western plant groups, so that on a map designed to show the distribution of our species analyzed according to their general range in Europe, the grouping of plants in the British Isles will be

found to be roughly north-western as opposed to south-eastern. The further change due to elimination of species has been already referred to. Most plants no doubt have spread in our islands as far as prevailing climatic and soil conditions allow, but in other cases the sea-barriers seem to have put a period to their natural advance. Considering the wide range of conditions of climate and soil under which, for instance, the Hairy Crowfoot (*Ranunculus sardous*), the Common Rock-rose (*Helianthemum Chamæcistus*), the Needle Furze (*Genista anglica*), and the Small Marsh Valerian (*Valeriana dioica*), occur in England, Wales, and Scotland, it is difficult to impute their absence from Ireland to climate.

Thirdly, we find (as we have already seen in the first chapter) varying conditions of soil intruding themselves and producing such local changes in the grouping of the plants as may quite obscure the broader differences just dealt with. Were our islands a plain formed of uniform materials, the gradual changes from south to north or east to west might be traced step by step. But their surface is most diversified; their rocks contain an epitome of the whole geology of Europe; the soils are consequently various: from the point of view of the plant world the area is an archipelago: for some plants a desert with occasional oases, for others an oasis enclosing occasional deserts. Certain species are confined to the Chalk—for instance, the Box (*Buxus sempervirens*) and the Stinking Hellebore (*Helleborus fœtidus*)—while to others a limy soil is a barrier comparable to that formed by the English Channel. It will be seen, then, that when we speak of the flora in general being

a reduced Continental one, many considerations, geographical, climatic, and edaphic, must be duly taken into consideration if we are to understand the composition and distribution of our vegetation.

But making all allowance for these various disturbing influences, there are found in our flora certain plant groups which will not fit in with this general conception of immigration from the east. Let us take a few examples. In fir woods in Dorset, until some forty years ago (when it was exterminated), grew a slender little plant allied to the Lilies, too little known to have a popular English name, and called by botanists *Simethis planifolia* or *S. bicolor*, the latter name having reference to the fact that the flower is purple on the outside, white on the inside. This plant is unknown elsewhere in Great Britain, and was at first set down by H. C. Watson, the leading British plant geographer, as an alien or denizen, not a true native; but the fact that it grows over a considerable area of very wild ground in Kerry (its only Irish station), far from possible sources of introduction, and undoubtedly native, indicates a strong probability of the plant's having been indigenous in Dorset also. It is not present on the adjoining parts of the Continent, but turns up again in the Pyrenean region, some 500 miles to the southward, and may be traced thence into Italy and North Africa. Did this instance of an apparent migration from the south stand alone, it might not excite much attention, and we should probably be inclined to attribute the plant's peculiar and discontinuous distribution to the extinction, perhaps by human agency, of intermediate stations. But it stands by no means alone. In Cornwall two

FIG. 28.—GREAT BUTTERWORT (*PINGUICULA GRANDIFLORA*).

[*To face p.* 173.

pretty Heaths (*Erica vagans* and *E. ciliaris*) are found, the latter spreading to Dorset. They occur in no other stations in the British Islands, and elsewhere only in the Pyrenean region. North Devon is the only home in Great Britain for the handsome Irish Spurge (*Euphorbia hiberna*), which in Ireland is distributed along the west and south coasts, being very abundant in Kerry. Outside the British Isles it also is confined to the Pyrenean area. Crossing into Ireland, we find along the south and west coasts no less than seven plants unknown in Great Britain, and elsewhere found only or mainly in the Pyrenees. Of these, three Heaths (*Erica mediterranea, E. Mackayi, Dabœcia polifolia*) are confined to Connemara and the Pyrenees; two Saxifrages, the London Pride (*S. umbrosa*) and the Kidney-leaved (*S. Geum*), with their Irish headquarters in Kerry, are likewise confined to the Pyrenean region. The beautiful Large-flowered Butterwort (*Pinguicula grandiflora*, Fig. 28), abundant in parts of Kerry and Cork, grows in South-west Europe and the Alps; while the Strawberry-tree (*Arbutus Unedo*, Fig. 29), so pleasing and unique a feature of the Killarney woods, ranges all along the Mediterranean. A little Orchid, *Neotinea intacta*, found on limy soils in Galway and the adjoining counties, and a Grass (*Schlerochloa festuciformis*) which occurs on sheltered shores on both the east and west sides of Ireland, are likewise confined elsewhere to the Mediterranean region. So it will be seen that along the south-western and western borders of the British Isles there is scattered a well-marked group of plants belonging to the Pyrenean and Mediterranean floras,

whose English or Irish stations are quite discontinuous with their nearest Continental habitats. Here clearly is something which calls for explanation; but before discussing the question attention may be drawn to a still more remarkable plant group of our western coasts, which mingles with the southern group referred to.

In damp meadows all round Lough Neagh, in the North of Ireland, grows an Orchid, *Spiranthes Romanzoffiana* (Fig. 30), whose greenish-white flowers possess a delicious fragrance resembling that of its ally, *S. spiralis*, the Autumnal Lady's Tresses. *S. Romanzoffiana* occurs also in Co. Cork, but we may search in vain for it throughout the rest of Europe. It is an American plant, widely spread throughout Canada and the northern States, and found on the Asiatic as well as the Alaskan side of Behring Sea. Again, in pools along the western Irish coast from Cork to Donegal, and also in the Hebrides, grows the Pipewort (*Eriocaulon articulatum*), a little aquatic with a tuft of grassy leaves from which a slender stem rises above the water, bearing a button-like head of small grey flowers. This plant also is absent from all the rest of Europe and from Asia, but widely spread in northern North America. The little Blue-eyed Grass of Canada (*Sisyrinchium angustifolium*), again, grows abundantly in many areas in the West of Ireland, where it would seem to be undoubtedly native, and is otherwise confined to North America. One or two other plants, of the same foreign distribution, have in Europe a less restricted range; they need not be mentioned individually, for enough has been said to show that along the western coasts of the British Isles

FIG. 29.—STRAWBERRY-TREE (*ARBUTUS UNEDO*) AT THE LAKES OF KILLARNEY.

FIG. 30.—*SPIRANTHES ROMANZOFFIANA* GROWING BY LOUGH NEAGH.

[*To face p.* 174.

there is a small but well-marked element in the flora which has its home in the northern portion of the New World; in our islands these species live side by side with the Pyrenean and Mediterranean plants lately dealt with. Here, then, is the problem set before us. How are we to account for the presence of these unexpected strangers in a flora derived in the main from a westward migration from the adjoining parts of the Continent, from which they are absent? And especially what are their relations to the Glacial Epoch, during which the Continental flora was forced far southward by the advance of the ice, while that of our own islands was probably greatly reduced, and the balance forced into limited refuges in the south-west, if it survived at all? It should at once be pointed out that these peculiar Pyrenean and American elements in our flora are matched by similar elements in the fauna. Into the zoological evidence we cannot go here, but one well-marked species of each geographical group may be mentioned. The Spotted Slug of Kerry (*Geomalacus maculosus*) is elsewhere confined to Portugal; while a little fresh-water Sponge, *Heteromeyenia ryderi*, widely spread in Irish lakes and rivers, and occurring also in Scotland, is otherwise exclusively American. In speculating, therefore, as to the origin of the plants, we must not leave out of account the question of the corresponding animals.

First of all, is it possible that these unexpected organisms were introduced into our islands by man? In an earlier chapter it has been seen how human trade and intercourse have imported into our flora plants from the uttermost ends of the Earth. May

we seek in this direction an explanation? The evidence is entirely against such a solution. These plants (and animals) are found chiefly—many of them entirely—in the wildest parts of the country, and bear fully the stamp of natives of old standing. Human foreign intercourse is not so old but that the introductions which it effected are still easily discernible to the student: the plants which have come to us thus bear the imprint of their origin; they spread outwards from centres of human activity, and are absent from undisturbed areas; they cannot in most cases compete with the indigenous vegetation, and only exist by confining their attempts at colonization to places where man has ousted the native flora—such as tilled land, roadsides, railway tracks. Even those aliens which have succeeded in winning a place among the native plants, such as the Monkey Flower (*Mimulus Langsdorfii*) or Michaelmas Daisies (*Aster* spp.) of North America, which are found sometimes in quite wild situations, the experienced field botanist detects readily enough. The introduction of the plants in question by man has never been advocated by a responsible biologist.

Assuming, then, that these groups owe their presence to natural agencies, the next question that arises is, Could they have come to our shores across the existing seas, or must we relegate their arrival to periods when different distribution of sea and land would aid their migration by allowing them to travel across a land surface, or at least to cross sea-barriers less wide than the present? This leads us to consider the means of dispersal possessed by the species in question, and to measure these against the nature

of the barriers they would have been called on to cross. An investigation on these lines would be lengthy, and out of place here. The reader has already from Chapter III. acquired some insight into the powers as well as the limitations possessed by seeds for crossing such barriers. Summing up the evidence briefly, it may be said that the seeds of none of the southern group float in water; consequently transport by currents is ruled out. Secondly, none of them is so light (see pp. 62-69) as to render it possible for them to cross the intervening sea by wind currents; very much the lightest seeds in the group are those of the Orchid *Neotinea intacta*, yet even these could not on any reasonable theory have been transported by wind from the plant's nearest station (in Southern France); the high speed of fall of the small seeds of the Pyrenean Heaths or Saxifrages renders their wind transport, even from the smaller distance which has to be reckoned with, in their case still more improbable. There is left, then, the agency of birds (see p. 70): can we look to these swift messengers for assistance? The rapid digestion of birds renders it futile to expect that even those which do not crush the seeds which they eat could bring over from the Pyrenees seeds which they have swallowed; so we are forced back on the uncertain method of ectozoic dispersal: that is, on the assumption that seeds of these plants have been imported by becoming entangled in the feathers of birds, or by adhering—possibly with the aid of mud—to their feet. That seeds are transported by these means has been shown by the observations of Darwin and other observers; but that the seeds of a number of different

plants, growing in different situations, should be brought thus from the Pyrenees and Mediterranean to our western coasts is a highly speculative suggestion. If we discard it, there is left the hypothesis that the plants migrated long ago overland, at a time when the western coastline of Europe was continuous and lay farther seaward. Such conditions have not occurred since the Ice Age; so we have to assume that the plants, arriving perhaps in Pliocene times by slow terrestrial dispersal, and subsequently cut off by invasions of the sea upon their line of advance, survived the cold and ice of the Glacial Period within the limits of our islands. That appears, on consideration of the geological evidence of widespread glaciation, sufficiently improbable; but we must remember that the evidence supplied by the plants is buttressed formidably by that of the corresponding animals, some of which, such as the Kerry Slug, are far less fitted for transmarine dispersal than are the seeds of plants. Also, we are faced with the problem of the American plants, and such organisms as the American Sponge, *Heteromeyenia:* a direct crossing of the ocean appears for them wholly impossible. Yet if they crossed over long-gone land surfaces, their arrival on this side of the Atlantic must be very ancient, and they must certainly have weathered successfully the Great Ice Age. The problem, it is clear, is an exceedingly difficult one, upon which it would be rash to pronounce any hasty opinion. Students of the subject have come to widely difficult conclusions: some holding with Edward Forbes that these Lusitanian and American organisms represent the very oldest element in our fauna and flora, having migrated over

bygone land surfaces in distant times and successfully survived the terrors of the Glacial Period; others claiming a much less remote period for their immigration. Indeed, one eminent recent writer on the subject, the late Clement Reid, considered that the Lusitanian plants are among the most recent arrivals in the country, their introduction being due mainly to birds driven by exceptional gales.

The question of the Lusitanian and American elements in our flora has been treated at some length both because it offers one of the most interesting problems in British botany, and because it affords a good illustration of the far-reaching nature of the questions which may lie behind the occurrence on our hills or in our valleys of even the humblest plant or animal. Each organism has a long record behind it, stretching far beyond the earliest periods of human history; and it is only by wide and patient study that we can hope to trace any portion of its story.

CHAPTER VIII

SOME INTERESTING BRITISH PLANT GROUPS

In the preceding chapters glimpses have been obtained of some of the wider aspects of plant life, particularly as seen on the hills and plains of our own country. The species composing our flora have been seen mostly, not as individuals, but as portions of regiments and armies, particular plants being mentioned but seldom, where required for purposes of illustration. In the final chapter it will be well to abandon this collective treatment, and glance at a few individual species or genera or small natural groups which possess features of interest of one sort or another. No systematic arrangement need be attempted: it will be pleasanter to ramble on, allowing our points of inquiry to turn up as they might on a country walk.

A consideration of abnormalities in the manner in which plants obtain their food-supply—irregular nutrition, as it has been called—will raise some interesting questions, and will bring us up against some of the most remarkable species which are found in the British flora. The outlines of the method by which plants manufacture their food are familiar to all, and have been referred to already (pp. 75, 132). The roots absorb from the soil water containing dissolved salts, which is passed up by the stems into the leaves. The leaves extract from the air carbon dioxide. The

chlorophyll, or green colouring-matter of the leaves, possesses the remarkable power in the presence of sunlight of breaking up and recombining these substances into the compounds which go to build up the plant-body. As has been pointed out, it is this power of forming organic out of inorganic matter that especially distinguishes plants from animals. But not all plants manufacture their food in this way. A large number feed like animals, finding their sustenance sometimes in living, more often in dead, organic material, either animal or vegetable. The whole enormous group of the Fungi do not possess chlorophyll, and in consequence are dependent on organic materials for their food. Some of the most familiar of the lower Fungi live on cheese, leather, bread, or any other damp animal or vegetable material. The higher forms, which decorate our woods and pastures, find their sustenance largely in leaf-mould. The groups of the Mosses, Hepatics, and Ferns, which are more highly organized than the Fungi, possess chlorophyll, and manufacture their own food; and it is with some little surprise, therefore, that when we come to the Seed Plants, the highest group of all, we find, though in relatively few cases, a reversion to the animal trait of using organic food. Some of our woodland plants have taken so entirely to a diet of leaf-mould that they have discarded the apparatus which would enable them to manufacture their own food. Chlorophyll, the magic wand by means of which the inorganic is transformed into the organic, and also leaves, the mills wherein the transformation takes place, are absent from these plants. For instance, the Bird's-nest Orchis (*Neottia Nidus-avis*),

FIG. 31.—BIRD'S-NEST ORCHIS (NEOTTIA NIDUS-AVIS). $\frac{1}{2}$.

sends up from a mass of fleshy roots a bare brown stem about a foot high, bearing a spike of brown flowers, the whole being so much of the same colour as the dead beech leaves among which the plant is usually found that it may easily be passed over. It is quite incapable of manufacturing its own food, but feeds on the decaying vegetable material which was manufactured by the trees under whose shadow it grows.

It is but a step from *saprophytes* such as this to *parasites*, which feed, not on dead, but on living organic matter. In the case of the higher plants, the hosts are always themselves plants, though, as pointed out on p. 78, they are, in the case of the Fungi, sometimes animals. One of the most interesting of these parasites is, like the Bird's-nest Orchis, found in woods—the Yellow Bird's-nest (*Monotropa Hypopitys*). This is, like the last, a leafless plant devoid of chlorophyll, sending up from a tangled root-mass one or more pale yellow stems, each bearing a drooping raceme of flowers of the same colour. The flowers show affinities to the Heath family (*Ericaceæ*), but the plant differs much from any other member of that Order. The Yellow Bird's-nest is always found associated with the *mycelium*, or cobwebby underground portion, of a fungus, on which it appears to be parasitic. The fungus is in turn a saprophyte, and the Seed Plant feeds at second hand, so to speak, on decaying vegetable matter. This parasitism of a seed plant on a fungus is a very exceptional case. A more frequent type is offered by the Broomrapes (*Orobanche*), which we may find in meadows, etc., growing on Clover, Thyme, Ivy, and so on. These

resemble the Bird's-nest Orchis in sending up a stout leafless stem crowned with a spike of flowers. The different species display almost every colour except green, being red or brown or purple or yellow, and one blue. These plants live by attaching themselves to the roots of their host, and drawing in the nourishment they need for their own growth—robbery pure and simple. The seeds of the Broomrapes are very numerous and very light, and of singularly primitive structure. When they develop, they produce, not a young plant with root and stem, but a delicate spiral filament which grows down into the ground. Should this meet with a root of its host-plant, it adheres to it closely, and grows into a swollen knob at the point of attachment, which when mature sends up the flowering stem already described. Should a suitable root not be met with, the filament withers away and dies as soon as it has exhausted the small amount of reserve food stored in the seed. A parasite of a less sedentary habit, to be found in spring in our copses and hedgerows, is the Toothwort (*Lathræa Squamaria*). This curious plant has underground creeping stems clothed with whitish, tooth-like, fleshy scales (curiously modified leaves). In autumn and winter the stems lie dormant. In spring they send out delicate roots which attach themselves to the roots of trees of various kinds and suck nourishment from them, with the aid of which the plant sends up into the air fleshy cream-coloured stems bearing many drooping flowers of the same hue, the structure of which shows that the plant is closely allied to the Broomrapes. The Toothwort is a very harmless parasite, and the species of Broomrape also, though sometimes abundant on

Clover, etc., do not do much damage; but the same cannot be said for the Dodders (*Cuscuta*), one of which is parasitic on Flax, another on Clover, and so on. These are little annual plants whose seeds lie dormant in the soil throughout the winter and well into the spring. Then the young plant, which has remained coiled up inside this seed like a spring, pushes forth in the form of a tiny thread. While one extremity fastens itself to the soil, the other rises up into the air, and its point slowly revolves. Should it come in contact with a living stem of a suitable plant, it attaches itself to it by means of disc-like suckers, penetrates the tissues of its victim, draws out nourishment, and, growing rapidly, spreads from plant to plant, taking a couple of close turns round each stem after the manner of a lasso, and then sending in rootlets from the attaching disc, and sucking the life out of each as it goes. It has no roots, no leaves, no chlorophyll, being of a red or yellow tint, and is entirely dependent for its nourishment on the plants which it attacks. In course of time—about August—an abundance of pretty little waxy-white flowers are produced, which produce the next year's supply of seed. A few seedlings of Dodder, developing under suitable conditions, will form a colony which is capable in its few months of life of sweeping over a large area, wrecking the vegetation on which it has battened.

A parasite of a quite different sort may be studied in the familiar Mistletoe (*Viscum album*). It is the only parasitic native plant which is shrubby, or which perches itself on trees (the seeds being spread by birds, which devour the white berries). It is not, like some parasites, particular as to the species upon which

it grows, flourishing equally upon a number of hosts, and even capable of living upon its own species. It differs from those parasites which we have been considering in possessing an abundance of green leaves, and being therefore capable of manufacturing its own food. At the same time, it has no roots which can penetrate the soil, and is incapable of an independent existence. It seems probable that its relations with its host are to some extent symbiotic—that is, each giving to the other—rather than purely parasitic, where the benefit is entirely on one side. The Mistletoe, retaining its leaves and manufacturing food throughout the year, is clearly capable of aiding its host, which loses its leaves in autumn, and cannot form fresh nourishment until spring is well advanced.

Before leaving this question of abnormal methods of procuring food as found among the higher plants, we may return for a few moments to the consideration of carnivorous plants, to which reference was made in Chapter IV. Of these the Sundews (*Drosera*), Butterworts (*Pinguicula*), and Bladderworts (*Utricularia*) supply very interesting examples within our own flora, which anyone may study on a holiday spent on the moors or mountains. The Sundews are familiar to all plant lovers—little plants of the bogland, usually growing among Sphagnum, and well distinguished by their leaves decked with spreading red hairs, each of which is tipped with a little drop of sparkling sticky fluid. It is these hairs or tentacles and their movements which place the Sundews among the most interesting of all plants. It is important to note that they are not hairs in the ordinary sense, which are organs of very simple structure arising from the

epidermis or skin of the leaf. The tentacles of *Drosera* have a complicated structure resembling that of leaves, and the tip is occupied by a gland which produces the sticky secretion already mentioned. These glands are exceedingly sensitive, and, moreover, sensitive in a selective way. They are unaffected by the drops of rain which frequently fall on them, but the touch of any solid body, especially of organic material, immediately affects them; most of all nitrogenous substances of any kind. Darwin found that a morsel of human hair weighing only $\frac{1}{78.740}$ of a grain was sufficient to set the machinery of *Drosera* in motion, and that immersion of a leaf in a solution of phosphate of ammonium so weak that each tentacle could absorb only $\frac{1}{20.000.000}$ of a grain acted as a strong stimulus. In nature the stimulus is usually given by some unwary insect—a midge or other small flying creature—which, attracted by the bright colour or by the odour of the leaf, ventures too close, and becomes entangled among the sticky hairs. Then a most interesting series of events takes place. Almost at once the tentacles—first the ones actually touched, and then the adjoining ones—bend towards the point of disturbance, closing down one by one on the unfortunate victim till the leaf resembles a closed fist. At the same time the production of secretion increases, so as further to entangle the victim. When it is firmly secured, the secretion changes in character. Digestive ferments, closely resembling those by which animals digest their food, are poured out. These dissolve the animal's body, all except the horny parts; the digested materials are then absorbed into the plant, which, as experiments show, benefits consider-

ably by the addition to its diet of this animal food. When digestion is completed, the tentacles open again and prepare for a fresh victim. While the details of this remarkable process have been worked out only by careful and minute research in the laboratory, the main movements may be watched by anyone on any British moorland; or, bringing home a few plants in the damp moss in which they grow, we may amuse ourselves by experiments in feeding them.

In comparison with the Sundews, the other insectivorous plants which are included in the British flora are of less interest. The Butterworts (*Pinguicula*), of which four species are known in these islands, have a rosette of smooth, broad, yellowish leaves covered with glands which exercise the same functions as those of *Drosera*. To the touch of raindrops, sand-grains, or other inorganic substances they are indifferent; but a tiny insect alighting on the sticky leaf at once provokes an outpouring of secretion, while the leaf rolls inward from the edges till the victim is securely caught; it is then digested as in the Sundew.

The Bladderworts (*Utricularia*), of which several species may be found floating in boggy pools, are rootless, limp plants with finely divided leaves, among which are numerous little bladders (in reality strangely modified leaflets), and upright stems bearing pretty yellow Snapdragon-like flowers. The bladders do not help the plant to float, and appear to have for their sole function the securing of animal food. In the Common Bladderwort (*U. vulgaris*) they are about $\frac{1}{10}$ inch long. At the upper end is a little hinged door, which is kept closed as by a spring against a thickened rim or door-frame. Outside the door are a few stiff

hairs, a convenient perching-place for small aquatic creatures such as the minute Crustaceans known as Water Fleas. Should one of these try to explore the bladder, the door opens easily, but closes at once behind the rash wanderer, imprisoning it. The Bladderworts do not *digest* the victims which they secure in this manner, but when the bodies are decomposed by means of bacteria, the products of decomposition are absorbed. How fatal this mouse-trap arrangement is to Water Fleas can be determined by dissecting the bladders of the plant.

Thus far, then, as regards some of those peculiar members of our flora which make their living by the unusual method of stealing their neighbour's goods, or which eke out their existence by the capture of animal food. Let us now take another line of exploration and consider the conditions which prevail on the loftiest portions of our islands, and how these affect the vegetation. Mountain-tops are always attractive and interesting places—the keen rarefied air, the freedom and openness of the summits, fill us with exhilaration. Our own mountains are not lofty; nowhere in the British Islands is a height of a mile attained. But we have only to ascend to a couple of thousand feet to note a great change in the vegetation. The plants of the lower grounds to a great extent die out (though some accompany us to our highest summit), and the vegetation takes on a low compact form, which becomes more emphasized as we ascend farther, till in sheltered nooks alone do we find any plants more than a few inches in height. Furthermore, we notice an incoming of new plants unknown at lower levels, which search will show us to be confined

to the mountains, each of them having a more or less definite limit below which (also above which, though our mountains are not high enough to render this point well marked) it is not found.

Among the plant formations and associations of the lower grounds which we considered in Chapter II. it was noted that the controlling factors were mainly connected with the nature of the soil and the amount of the water-supply. Here on the mountains another factor, the climatic, comes in emphatically, and takes charge. The temperature of the atmosphere falls one degree centigrade for about every 200 feet of elevation, so that a sharp frost on the lowlands may easily mean zero Fahrenheit on a 4,000-foot hill. The rarefaction of the atmosphere, too, tends to produce a much greater range of temperature, both diurnal and seasonal. Again, the velocity of the wind is much higher on the summits than on the plains, where friction is greatly increased by trees and other obstacles. These high winds have a very great cooling effect, as we may notice on our own bodies even in summer. In fact, as regards climatic change, an ascent of a thousand feet is comparable to a journey of several hundred miles northward. Anyone who has, on a winter tramp, been caught in a snowstorm on a 3,000-foot hill is forcibly reminded of what he has read of winter conditions in the Arctic regions. In ascending Ben Nevis we travel, in a sense, to the Arctic Circle. But the analogy is false, for conditions, especially in summer, are very different in the two places. The plants of our mountains have all the advantages of the high summer elevation of the sun, very different from the weak, sloping sunlight of the

FIG. 32.—ALPINE PLANT-BOSS (*SILENE ACAULIS, HYMENOPHYLLUM UNILATERALE, MNIUM HORNUM*).

[*To face p.* 191.

Arctic. On our loftier hills, indeed, the heat is on occasions oppressive.

Again, the mountain climate, with its heavy rainfall and long cold period, tends to the formation of peat; and the acids thus engendered in the soil, as well as the low temperature prevailing during most of the year, render difficult the absorption of water by the roots of plants. The conditions under which alpine plants, then, live may be summed up as follows: a long cold winter, a short summer; great exposure; scarcity of food-supply. The modifications which plants have undergone to meet these conditions are very marked, and render alpine plants a source of constant interest to the traveller and of delight to the gardener. The effect of low temperature (also of peaty soil) in rendering difficult the absorption of food materials, and causing extensive root production and limited stem and leaf growth, is immediately observable. In Fig. 33 is seen an alpine Stonecrop (*Sedum primuloides*) as growing on the Chinese Alps at some 12,000 feet. The root is out of all proportion to the aerial parts. The same plant in the garden forms a little bush with branching stems half a foot long, and flowers borne on leafy axillary shoots a couple of inches long, while the roots are short and tufted. The most characteristic form which alpine plants assume may be called the cushion type. This is produced by excessive branching of the stems of small-leaved plants, accompanied by but little longitudinal growth; and it is excellently shown in many well-known plants such as the Mossy Saxifrages, the Kabschia Saxifrages, the Cushion Pink (*Silene acaulis*), and a number of others. The same type of

FIG. 33.—SEDUM PRIMULOIDES. $\frac{1}{1}$.

plant growth is characteristic of semi-desert regions, where the points of similarity of environment to those of the mountain-tops are evident. This cushion form has many advantages for the alpine plant. It keeps it warm in winter and cool and damp in summer; it allows it to produce a great amount of blossom without the necessity for extensive growth; it resists the utmost efforts of furious gusts of wind almost as well as would a half-buried stone; on the most storm-swept cliffs its fresh green blobs "welcome every changing hour, and weather every sky." Fig. 32 shows a boss of this kind, composed of the Cushion Pink (*Silene acaulis*), with an admixture of Filmy Fern (*Hymenophyllum unilaterale*) and a Moss (*Mnium hornum*). The shrubs of the alpine zone are mostly small and creeping, weaving themselves among the vegetation, and with low grasses and sedges forming a mat which is equally resistant to all inimical conditions. Their leaves are small, to avoid damage by wind or by excessive transpiration. In some genera—for instance, *Veronica*—the diminution of leaf surface accompanying more elevated habitat is very striking. In the New Zealand lowlands broad-leaved forms (Fig. 34, *left*) are met with, which give way, as one ascends to 8,000 feet, to such forms as *V. Hectori* (Fig. 34, *right*), in which the leaves are reduced to mere scales, and the plant much resembles some of the Cypresses or other Conifers with marked xerophile characters.

Other plants, again, escape climatic rigours by burrowing underground and throwing up short aerial stems in summer; the spindly plants of the lowland, with diffuse stems, and also the light-rooted annuals,

are conspicuous by their absence. The brief summer and long winter are unsuitable to the economy of annual plants; and the alpine perennials are so constructed that with the passing away of the cold, flowering and fruiting may be accomplished quickly, before winter descends again. The abundance and

FIG. 34.—NEW ZEALAND SHRUBBY VERONICAS, SHOWING, FROM LEFT TO RIGHT, REDUCTION OF LEAF WITH INCREASING ELEVATION OF HABITAT. $\frac{2}{3}$.

vividness of the flowers of alpines is almost proverbial. Several explanations have been put forward to account for these features, and probably there is some truth in each of them. It has been held that the brilliancy of the sunlight is accountable; the shortness of the period available for seed-production, and the consequent need of prompt pollination by insects, have been suggested,

as leading to urgent advertisement by means of brilliant coloration; while the fact that the pollinating insects are largely Butterflies, the most æsthetic of flower visitors, has also been put forward as accounting for it. Be that as it may, the glowing patches of colour produced by many quite minute alpine plants

FIG. 35.—MOUNTAIN AVENS (DRYAS OCTOPETALA). $\frac{1}{1}$.

are among the most delightful things in nature. Our own flora contains but few of the more striking of these jewels; but where will one find a more delightful sight than a well-flowered patch of Spring Gentian (*G. verna*) or Mountain Avens (*Dryas octopetala*) or Purple Saxifrage (*S. oppositifolia*)?

As we mount higher and higher on the hills, plants become fewer and more stunted, but hardy forms persist even long after the level of perpetual snow is reached. In the Alps, *Ranunculus glacialis* occurs up to an elevation of about 14,000 feet. In West Tibet, strange stunted species of *Saussurea*, a genus of *Compositæ* allied to the Thistles, exist at elevations of 17,000 to 19,000 feet. Some of the Cryptogams go higher still. Lichens grow on the summit of Kilimanjaro (over 19,600 feet); and Schimper suggests* that this may by no means represent the absolute limit of vegetation. The prevalence of snow and ice does not of itself inhibit the lower forms of life. Since "red snow" was shown, nearly a century ago, to be due to colonies of a minute Alga, many microscopic organisms of like habitat have been discovered, and these algal colonists of snow and ice are now known to extend far over the frozen deserts of the highest hills, and to penetrate into the remotest regions of the Arctic and Antarctic.

As we get up to the level of perpetual snow on the higher mountains, or go northward within the Arctic Circle, the conditions under which plant life exists become very severe. It has been pointed out that in spite of a superficial similarity, wide disparity exists between the sets of conditions prevailing in the two kinds of habitat just mentioned. In the Arctic the winter is continuously dark and the summer continuously light; and in summer the sun is never far above the horizon, so that the temperature remains low, though it rises amply far enough above freezing-point

* A. F. W. Schimper: "Plant Geography" (English translation, 1903), p. 719.

to allow of plant life. On high mountains, on the other hand, there is the same succession of day and night which prevails on the plains below, the height of the sun above the horizon being a question of latitude. On mountain-ranges situated within the Temperate Zone, such as the European Alps, and much more on those nearer the Equator, the day temperature in summer is very high wherever the sun strikes, and while plants may have to withstand at night a temperature comparable to that borne by the Arctic flora, they must endure by day the most intense insolation.

Neither in the Arctic nor on the high hills does plant life cease merely on account of low temperature. Species belonging to many families venture even beyond the limit of perpetual snow. The coldest known area on the earth's surface lies in Siberia, actually within the limits of forest growth, and trees and herbs of many species survive winter temperatures which may fall below -60° C. (76 degrees of frost Fahrenheit). They freeze into solid lumps of ice without injury, and indeed the thawing process in spring is more dangerous to them than their congealment in autumn. Many of the high alpine plants are frozen solid every night only to be roasted alive by day; it seems amazing that any living organisms can endure under such circumstances. Yet it is not only species confined to areas where such extremes exist, and specially adapted thereto, which can resist them successfully. In Central Europe the Common Chickweed and Common Daisy are often frozen solid, so that leaves and stems snap between the fingers like sealing-wax, yet with a rise of temperature they continue growth quite unperturbed, just as they do in areas where frost is unknown. The

main difficulty induced by cold would appear to be the withdrawal of available water; if that goes on for too long, life ceases. Of course the suspension of activities which accompanies freezing cannot continue indefinitely, and in the cold regions of the Earth plants are found only where for a sufficient portion of the year the maximum temperature rises above freezing-point enough to allow of ordinary vital functions being resumed. A curious point in this power of resistance in plants to extremes of temperature is that they display no obvious protective adaptations. "Our present powers of investigation," Schimper concludes,* "do not enable us to recognize in plants any protective means against cold. The capacity of withstanding intense cold is a specific property of the protoplasm of certain plants, and is quite unassisted by protective means that are external."

It is a far cry from the high Alps to the seashore, but it will be of interest to examine next the lower limit of the range of the Seed Plants. While the upper limit varies much in different latitudes, according to the distribution of temperature, the lower is controlled by sea-level, which (for our purpose at least) is uniform over the whole globe. The level of the fresh waters, whose margin marks the limit of the bulk of the Seed Plants, is, on the other hand, various, lakes being situated at different heights above (and occasionally below) sea-level, while rivers slope across the lands down to the ocean. While the sea margin forms a very real barrier to the spread of Seed Plants, the lakes and rivers, on the other hand, yield many

* A. F. W. SCHIMPER: "Plant Geography" (English translation, 1903), p. 41.

inhabitants, and we must examine the relations existing between the aquatic and the terrestrial species.

As has been stated on a former page, the evidence points to life having originated in the water, at a period extremely remote. The most lowly as well as the most minute of all organisms are the bacteria, some of which are in size beyond the limit of the most powerful microscope to detect, their presence being known only by their chemical actions. The most primitive groups of bacteria, known as prototrophic, are able to live without light, deriving their nourishment by the breaking up of inorganic chemical compounds. It is difficult to conceive of any living organism more primitive than these, and quite possibly they recall that dim borderland where merely chemical structure and action mysteriously advanced into the cell structure and purposive chemical changes which we call life. From that lowly stage the evolution of plant life has been marked especially by three great forward bounds, of inestimable importance. The first of these was the "invention" of chlorophyll, which allowed plants to use for their life-processes the vast supply of energy furnished by the Sun. Sunlight then became essential to life, and the Algæ, the probable ancestors of all the higher plants, were developed, presumably through the peculiar *Cyanophyceæ*, or "Blue-green Algæ," in which the chlorophyll is in a somewhat undifferentiated condition. Much later than this stage, yet far back in the history of evolution, occurred the second of the great forward steps. This was the desertion of the water for the land, which opened up for the plant world vast new fields and a great variety of new conditions. The final stage was

reached by the abandonment of the aquatic mode of pollination by means of swimming spermatozoids, as still found in the Maidenhair Tree (*Ginkgo*), Cycads, Ferns, and groups lower in the scale, and the adoption instead of pollination through the medium of the air, "which" (to quote Mrs. Arber's happy phrase) "has won for them the freedom of the land." The Seed Plants, then, achieved their wonderful abundance and variety owing to the highly stimulating conditions offered by a terrestrial existence; we must assign to all the existing types a long terrestrial ancestry. How, then, about the water plants whose leaves and flowers so decorate our lakes? There seems no doubt* that they are species which have left the land to resume the aquatic habits of their remote ancestors. With few exceptions they retain the aerial mode of pollination which is the pride of the specialized land plants. The pressure of competition has probably driven them into the water, where they descend as far as the lessening light-supply will allow. Some—presumably the earliest to take to an aquatic life—have all their relations to keep them company, the remote ancestor which adopted an aquatic habit being now represented by many species, or even by many genera. In other cases a terrestrial genus or order has few or only a single aquatic representative. It may be assumed that in such a case the aquatic habit has been recently acquired. The great majority of water plants send their flowers up above the surface to be pollinated by wind or (more rarely) by insects. It may be noted that few of the more highly evolved groups of Seed

* See Agnes Arber: "Aquatic Angiosperms: the Significance of their Systematic Distribution," *Journal of Botany*, 1919, p. 83.

Plants are represented in the aquatic flora; wind-pollinated flowers of a rather primitive type of structure are the rule in our lakes and rivers; which points to an early assumption of the aquatic habit, and suggests that the land is more favourable than the water for the evolution of higher types.

While the fresh waters of the globe have thus acquired from the land an abundant population of higher plants, the presence of salt, in water as on land, has had a deterrent effect. The sea was at first fresh. The primitive ocean derived by condensation from a cooling atmosphere in the early days of the world's history contained no excess of salts. Whether life arose while this condition still persisted it is not possible to say; but as the sea grew salter owing to the rivers bringing into it incessantly salts derived from the land, the Seaweeds alone of the great groups of plants adapted themselves to saline conditions, and the ocean is now their unchallenged kingdom. The divisions which are represented by the Mosses, Liverworts, Club-mosses, Horsetails, and Ferns, have not, and so far as is known never had, a single representative in the sea. Only one or two Fungi—often symbiotically combined with Algæ to form Lichens—and a very few Flowering Plants, have attempted marine colonization, after long ages spent on land; and they have met with indifferent success. As we pass from fresh to brackish water, the population decreases rapidly, till in the seas surrounding our islands only one Seed Plant—the Grass-wrack, *Zostera marina*—has adopted a habitat which is thoroughly marine, and very few are found in other parts of the world. A study of the meeting-ground of the land

and sea plants, such as we may make on rambles along the coast, supplies us with some interesting material. On sandy shores, the wave-trampled beach, shifting under the influence of winds and currents, offers a stretch of "no-man's-land"—a desert strip untenanted alike by terrestrial or marine plants. The former do not descend below spring-tide mark, if they go so far; the latter cannot obtain foothold on the unstable substratum. The peculiar characters of the terrestrial beach plants has been referred to on a previous page (p. 36). On rocky shores the "desert" strip is much narrowed, and a certain overlap may often be found, for the Lichens—essentially a terrestrial group—descend from the plant-covered slopes into the spray-swept zone below, and on to mix with the Seaweeds which occupy the belt under high-water mark, some of them, species of *Verrucaria* and *Arthropyrenia*, continuing downward till the low-water mark of spring tides is reached. On steep rocky shores the dividing-line between the Flowering Plants and the Seaweeds is quite narrow, and varies in elevation with the exposure. On cliffy coasts open to the Atlantic waves the uppermost Seaweeds, such as *Pelvetia*, which only asks to be wetted periodically by spray, occur far above high-water mark, the lowest Seed Plants perching on the rocks much higher still—sometimes not venturing to within 100 feet of the water-level. Under such extreme conditions none of the higher land plants venture down towards the unfriendly sea. To see the overlap of the terrestrial and maritime vegetation well developed we seek conditions entirely different, where amid shallow inlets and salt-marshes land and sea merge imperceptibly.

Here the absence of higher plants from the areas below high water, as compared with their abundance above water-level, is a conspicuous feature. This is a noteworthy point, because if we assume that the presence of salt is the main factor which has prevented the land plants from spreading downwards, we are faced with the fact that the soil of the salt-marsh, where many such plants occur, may by evaporation of water become much more highly charged with salt than the sea itself. Yet the salt-marsh flora includes representatives of many Natural Orders, including some of the most highly specialized families—*Ranunculaceæ* (*R. sceleratus*), *Cruciferæ* (*Cochlearia* spp.), *Caryophyllaceæ* (*Alsine*), *Umbelliferæ* (*Apium graveolens*, *Œnanthe Lachenalii*), *Compositæ* (*Aster Tripolium*, *Artemisia maritima*), *Primulaceæ* (*Glaux maritima*), *Plumbagineæ* (*Statice*, *Limonium*). It seems clear that it is the assumption of the marine habit which is the stumbling-block, not the presence of salt. The Grass-wrack or *Zostera*, our only marine Seed Plant, comes of one of the oldest stocks of aquatic plants, and its nearest relatives have long been toying with the idea of a maritime habitat. The Order to which it belongs, the *Naiadaceæ* or Pondweed family, from their worldwide range, their number, their variety, and their uniformly aquatic habit, may be set down as among the earliest Seed Plant colonists of lakes and rivers; some of them favour brackish water, while others besides the Grass-wrack have taken to marine life. Without going beyond the limits of our native *Naiadaceæ* we can study the various stages, and form a picture of how the Grass-wrack migrated to the sea. First we have the

numerous Pondweeds which grow in our lakes and rivers—plants with leaves broad and floating, or narrow and submerged, and inconspicuous flowers which rise above the water and are pollinated by the wind. Next we find several narrow-leaved Pondweeds which grow in brackish pools; and with them are some allies, the Tassel Pondweed (*Ruppia*) and Horned Pondweed (*Zannichellia*), with more reduced flowers and often a more nearly marine habitat, as they sometimes mix with Seaweeds on the open shores of estuaries; in these plants we find the stages of a most interesting return to the archaic method of water-pollination, so long discarded by the great mass of the Seed Plants. In the flower of *Ruppia*, which consists merely of two stamens and four carpels without corolla or calyx, the pollen is liberated under water, and, being light, rises to the surface; older flowers have already, by growth of the flower-stalk, reached the surface, and they become pollinated by the floating grains. In *Zannichellia* the process is in general similar, save that the flowers are either male or female, the former consisting of nothing but a single stamen. The Naiads (*Naias*) form an allied genus, and are slender annual herbs, growing completely submerged in fresh or brackish water. One of them (*N. flexilis*) occurs in lakes at rare intervals along the western edge of the British Isles; and another, *N. marina*, is found living in only one spot in Britain—Hickling Broad in Norfolk; their fossil seeds embedded in old lake deposits show that in former times both were more widely spread than now in Western Europe, and that other species of the genus also occurred. In the Naiads complete rever-

sion to water-pollination is found. When the very simple male flowers shed their pollen, the grains, which are heavy owing to the presence of starch, fall through the water on to the female flowers which are borne below them, or are carried by currents to other flowers. Lastly we come to the Grass-wracks, a small group of submersed marine plants. While some of them, like our little native *Z. nana*, haunt muddy sands between tides, our more familiar species, the common *Z. marina*, is thoroughly marine, growing tall and vigorous among the large Seaweeds down to far below low-water mark (to over 30 feet in the Baltic). The plant has, nevertheless, not yet developed submersed pollination, the pollen-grains rising to the surface, where they are caught by the stigmas of floating female flowers. It follows that the individuals rooted in the deeper water, though growing vigorously, do not mature seed, for the production of which the species has to rely on plants which, at least at low water, are rooted sufficiently near the surface to allow the flowers to rise above it. Could the species achieve submersed pollination, it appears quite capable of colonizing throughout the Laminarian zone, wherever there is a soft substratum for its creeping stems.

The land plants of the salt-marsh, as well as the aquatic species, furnish interesting examples of overlap with the sea flora, but a brief reference must suffice. The Glasswort (*Salicornia*), for instance, has furnished itself with a very complete equipment for the difficult conditions of salt-marsh life (see pp. 17, 18), and grows far out on the mud-flats in green colonies, often below the upper limit of the Bladder-wrack or *Fucus*,

the common brown Seaweed of our shores. The Glasswort has discarded leaves, its stems have become thick and succulent, and its flowers, reduced to the minutest and simplest dimensions, are almost buried in the fleshy branches. Thus armed, it braves the salt-desert of the mud-flats, and repeated submersion by the tides leaves it uninjured. Under the peculiar conditions of its life, it relies neither on insects nor wind nor water for pollination, the flowers being self-pollinated. A more surprising commingling is that which is illustrated by A. D. Cotton in his report on the Seaweeds of the Clare Island district (*Proc. Royal Irish Academy*, vol. xxxi., 1912), where, on peaty soil a little above mean high-tide level, the Sea Pink is shown forming a sward with a peculiar dwarf form of *Fucus* (*F. vesiculosus*, var. *muscoides*) and a few other salt-marsh Seed Plants, such as *Schlerochloa* (*Glyceria*), *Glaux*, *Salicornia*. The Sea Pink is highly evolved florally, and differs widely from the Saltwort in its abundant production of leaves and showy flowers, the absence of any conspicuous xerophile characters, and the fact that it is not confined to the coasts, being often a member of the alpine flora of our higher hills. In its association with *Fucus* it may be claimed that it is the latter which is "out of water," as it never produces fruit, increasing solely by means of vegetative growth. At the same time, so closely does it press its partner in the struggle for room, that the Sea Pink fails to form its usual robust clumps, its stem being mostly unbranched and its stature dwarfed.

Viewing generally the migration of the Seed Plants from land to water, we see that the fresh waters of the world, untenanted by other large plants, have been

fully colonized, generally a long time ago, and by plants of rather early types. But as regards the sea, the luxuriant Algal vegetation which is in possession of our shores has no reason to tremble for its supremacy. Beautifully adapted for their life, whether in sheltered bays or on stormy rocks, the Seaweeds show no sign of relinquishing the domain that has been theirs since the earliest rocks which still display traces of organic life were laid down in Cambrian seas.

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